NVO - 61

PROJECT RULISON

POST-SHOT

PLANS AND EVALUATIONS

DECEMBER, 1969

UNITED STATES ATOMIC ENERGY COMMISSION

NEVADA OPERATIONS OFFICE

LAS VEGAS, NEVADA

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for E. Williams
Robert E. Miller
Manager

ESC:EDC-1584

Enclosure:
NVO-61, December 1969

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PROJECT RULISON

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PLANS AND EVALUATIONS

DECEMBER, 1969

UNITED STATES ATOMIC ENERGY COMMISSION

NEVADA OPERATIONS OFFICE

LAS VEGAS, NEVADA

RULISON SITE

POST-SHOT PLANS AND EVALUATIONS - PROJECT RULISON

BACKGROUND

Project RULISON is a joint experiment sponsored by Austral Oil Company, Incorporated, of Houston, Texas; the U. S. Atomic Energy Commission; and the Department of the Interior. Program management is provided by CER Geonuclear Corporation of Las Vegas, Nevada, under contract to Austral. The purpose is to study the economic and technical feasibility of using an underground nuclear explosion to stimulate production of natural gas from the low productivity gas-bearing Mesa Verde formation in the RULISON Field of western Colorado. The project site is in Section 25, Township 7 South, Range 95 West, of Garfield County, about 6 miles SE of the town of Grand Valley. Elevation at the surface ground zero is 8,154 feet above sea level.

The RULISON experimental program is divided into three phases. Phase I included drilling a pre-shot exploratory well, performing pre-shot gas production tests, and geological, hydrological and other studies for technical and safety confirmation. The emplacement hole was drilled as a part of Phase I.

Phase II included surface construction, emplacement of the explosive, detonation and measurements of immediate detonation effects. The second phase of the RULISON experiment was completed with the detonation of a 40-kiloton yield nuclear explosive on September 10, 1969. The explosive had been emplaced at a depth of 8,431 feet through a 10-3/4 inch steel casing that was filled to the surface with stemming materials to contain the energy of the explosion and resulting radioactivity under ground.

A delay of at least six months is scheduled before reentry. During this time, the radioactivity in the underground cavity created by the explosion will decay to less than a thousandth of that present twelve hours after the detonation.

Phase III of the experiment involves controlled drillback into the cavity and flow testing to determine the cavity volume and the rate at which natural gas flows from the low permeability reservoir.

PROJECT RULISON POST-SHOT PLANS AND EVALUATIONS

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INTRODUCTION

Project RULISON post-shot plans and evaluations have been made in accordance with the policy prescribed in Section 012 of AEC Manual, Chapter 0524, "Standards for Radiation Protection," which states that:

> "AEC and AEC contractor operations shall be conducted in such a manner as to assure that radiation exposures to individuals and population groups are limited to the lowest levels technically and economically practical."

The planned experimental program to determine the results of the explosion will include the following:

Reentry into the RULISON cavity, commencing not earlier than 180 days after the shot. During this period a few curies of gaseous radioactivity may be released.

Short-term, high-rate flow tests under various meteorological conditions to assure operational readiness of monitoring systems. The maximum volume of gas to be flared during these tests will probably be less than 20 MMSCF (million standard cubic feet).

Short-term, high-rate flow testing to evaluate the cavity volume. During this time, 5% to 40% of the gaseous radioactivity may be released. Flow rates of natural gas as high as 20 MMSCF per day may occur. The anticipated total volume to be flared in these tests will be 100 - 200 MMSCF. Time duration, including shut-in time for buildup between flows, is expected to be about 3 weeks.

Intermediate term, lower rate flow tests to evaluate dimensions and flow characteristics of the fracture zone. During this time, 5% to 30% of the total gaseous radioactivity may be released. The anticipated total volume of gas to be flared in these tests will be 100 - 200 MMSCF. Maximum flow rates of 5 MMSCF per day may occur. Time duration will be about 2 months.

During long-term production testing and partial buildup, 5% to 40% of the total gaseous radioactivity may be released. Maximum flow rates of 5 MMSCF per day may occur, with the total volume of gas flared to be 300 - 600 MMSCF. Time duration is estimated to be 6 - 8 months.

These plans should be understood to be subject to changes arising from the actual conditions encountered during reentry and testing.

The radiological safety criteria for the RULISON Project were provided in a teletype from the Director, Division of Peaceful Nuclear Explosives, AEC Headquarters to the Manager of the AEC Nevada Operations Office, dated April 11, 1969, the pertinent part of which is quoted below:

> "Post event activities for Project RULISON will be conducted under AEC MC 0524, Appendix 0524, Section IA - individuals in controlled areas, and Section IIA - individuals and population groups in uncontrolled areas."

Radiation exposures to the population around the RULISON site during and following the flaring operations are predicted to be negligible. Even under the condition of the postulated "maximum hypothetical" accident, operations will be conducted so as to keep the radiation exposure to the nearby population well below the Radiation Protection Guides and still further below the levels of the Protective Action Guides recommended by the Federal Radiation Council.

1. PHYSICAL CHARACTERISTICS OF THE RULISON CAVITY

Diagnostic data obtained at the time of detonation, as well as preliminary reports on measurement of ground motion by USC&GS and Sandia Corporation, indicate that the RULISON device behaved about as expected, i.e., a nominal yield of 40 kilotons.

The geophones near surface ground zero showed a burst of noise commencing at 48 seconds after detonation and lasting until about 150 seconds. This is consistent with prompt collapse of the cavity to form a chimney as might be expected where the cavity pressure arises mostly from vaporized rock with low water content.

Environmental Research Corporation predictions of cavity dimensions for nominal yield, together with the chimney volume and the void space in the chimney (i.e., the cavity volume), calculated from their predictions, are given in TABLE 1-1.

TABLE 1-1

	Maximum	Mean	Minimum	Units
Cavity Radius	108	90	72	feet
Cracking Radius	580	485	390	feet
Chimney Height	451	376	301	feet
Cavity Volume (or Chimney Void Space)	5.28×10^6	3.05×10^6	1.56×10^6	ft^3
Chimney Volume	16.5×10^6	9.57×10^6	4.90×10^6	ft^3

2. PRESSURE AND TEMPERATURE EXPECTED IN THE CAVITY

The pressure in the cavity six months after the detonation, based upon wellhead pressures observed subsequent to detonation, is expected to be within 50 psi of the initial reservoir pressure (2940 psi).

The ambient temperature of the gas in the cavity six months after the detonation is estimated to be $375^{\circ} \pm 25^{\circ}$ F.

3. AMOUNT, NATURE AND DISTRIBUTION OF RADIOACTIVITY IN THE CAVITY

Radioactive nuclei are created in the course of a nuclear detonation by fission and neutron activation. Species which are not gaseous at the temperature of molten rock (1500° - 2000° C) are entrained in the melt. Most of the rest plate out on the cool rubble as it falls through the gas. A few species are gaseous at normal temperatures or arise by radioactive decay of normally gaseous elements, especially the noble gases Xe and Kr. Some fraction of these species are widely distributed throughout the rubble. Fission product chains giving rise to such species are shown in TABLE 3-1.

Computer calculations were made to determine the fission products remaining in the cavity 180 days after the detonation. Additional calculations were made of radioactive species arising from neutron activation of device components and the surrounding rock. The result of these calculations is shown in TABLE 3-2. The tritium will be distributed among several chemical species which include hydrogen gas, water, tritiated methane and other tritiated hydrocarbons; the exact partitioning of the tritium among these species will be a function of the thermodynamics of chemical reactions occurring in the cavity, and will vary over a period of time.

4. REENTRY PLAN

Objective

It is intended that the reentry into the chimney, which was formed in the R-E Well by the detonation of the nuclear device on September 10, 1969, be made through the R-EX Well which is located on the surface approximately 311' southeast of the R-E Well (emplacement hole). All materials and procedures used will be in compliance with State of Colorado Oil & Gas Conservation Commission rules and regulations and all work will be accomplished in a workmanlike and prudent manner.

Prior to the commencement of the reentry drilling operations in R-EX, preliminary operations involving R-E (Emplacement Well) will be undertaken to determine the ability of the Emplacement Well to produce natural gas and to collect and analyze samples of the gas produced to determine the nature of the radioactive species and hydrocarbon components contained in the gas.

TABLE 3-1 SELECTED FISSION PRODUCT CHAINS

Nuclide	Half Life	Radiation (Including Daughters) (d)	Chain of Formation
^{85}Kr	10.4 y.	99% β^- 0.67 MeV	40 s ^{85}Se →
		1% β^- 0.15 γ 0.52	3.0 m ^{85}Br →
			4.4 h $^{85}Kr^m$ →
			10.4 y ^{85}Kr → stable ^{85}Rb
^{89}Sr	50.4 d.	100% β^- 1.46 MeV	4.5 s ^{89}Br →
			3.2 m ^{89}Kr →
			15.4 m ^{89}Rb →
			50.4 d ^{89}Sr → stable ^{89}Y
^{90}Sr	28 y.	100% β^- 0.54 MeV	1.6 s ^{90}Br →
		β^- 2.27 (d)	33 s ^{90}Kr →
		.02% γ 1.739 (d)	2.7 m ^{90}Rb →
			28 y ^{90}Sr →
			64.3 h ^{90}Y → stable ^{90}Zr
^{131}I	8.05 d.	β^- 0.61 MeV 87%	3.4 m ^{131}Sn →
		0.25	23.1 m ^{131}Sb → 29h $^{131}Te^m$ (.15)
		0.81	^{131}Sb → 24.8m ^{131}Te (.85)
		γ 0.36 82%	29 h $^{131}Te^m$ → 8.05d ^{131}I (.8)
		0.63 9%	
		Others	$^{131}Te^m$ → 24.8m ^{131}Te (.2)
			^{131}Te → 8.05d ^{131}I
			^{131}I → 12d $^{131}Xe^m$ → stable ^{131}Xe (.008)
			^{131}I → stable ^{131}Xe (0.992)
^{137}Cs	30 y.	92% β^- 0.52 MeV, γ.66	24.2 s ^{137}I →
		8% β^- 1.18	3.9 m ^{137}Xe →
			30 y ^{137}Cs → 2.57m $^{137}Ba^m$ (.092)
			^{137}Cs → stable ^{137}Ba (0.08)
			2.57 m $^{137}Ba^m$ → stable ^{137}Ba

TABLE 3-2

FISSION-PRODUCT AND NEUTRON-INDUCED ACTIVITY IN CAVITY - 180 DAYS AFTER DETONATION

Nuclide	Half Life	Curies
^{85}Kr	10.76 y	0.96×10^{3}
^{89}Sr	50.6 d	0.91×10^{5}
^{90}Sr	28.8 y	0.59×10^{4}
^{91}Y	59 d	1.01×10^{5}
^{95}Zr	65 d	1.82×10^{5}
^{95}Nb	35 d	0.32×10^{6}
^{103}Ru	40 d	0.41×10^{5}
^{103}Rh	57 min	0.41×10^{5}
^{106}Ru	1.0 y	1.52×10^{5}
^{106}Rh	30 sec	1.52×10^{5}
^{131}I	8.05 d	1.13
^{133}Xe	5.27 d	0.86×10^{-3}
^{137}Cs	30 y	0.75×10^{4}
^{137}Ba	2.6 min	0.69×10^{4}
^{140}Ba	12.8 d	0.34×10^{3}
^{140}La	40 h	0.40×10^{3}
^{141}Ce	32.5 d	0.52×10^{5}
^{143}Pr	13.7 d	0.63×10^{3}

TABLE 3-2 (Cont'd)

Nuclide	Half Life	Curies
^{144}Ce	285 d	1.47×10^5
^{144}Pr	17.3 min.	1.47×10^5
^{147}Pm	2.6 y	0.28×10^5
^{3}H	12.26 y	10^3 to 10^{4*}
^{37}A	34.3 d	10 to 10^{2*}
^{39}A	260 y	2 to $2 \times 10^{1*}$
^{14}C	5770 y	10^{-2} to 10^{-1*}

*Produced by neutron activation.

History - R-EX Well

After production testing from the R-EX Well, and prior to the detonation of the nuclear device in the R-E Well, the R-EX Well was placed in a state of temporary abandonment through means of filling the casing with cement and water. (Figure 4-1.)

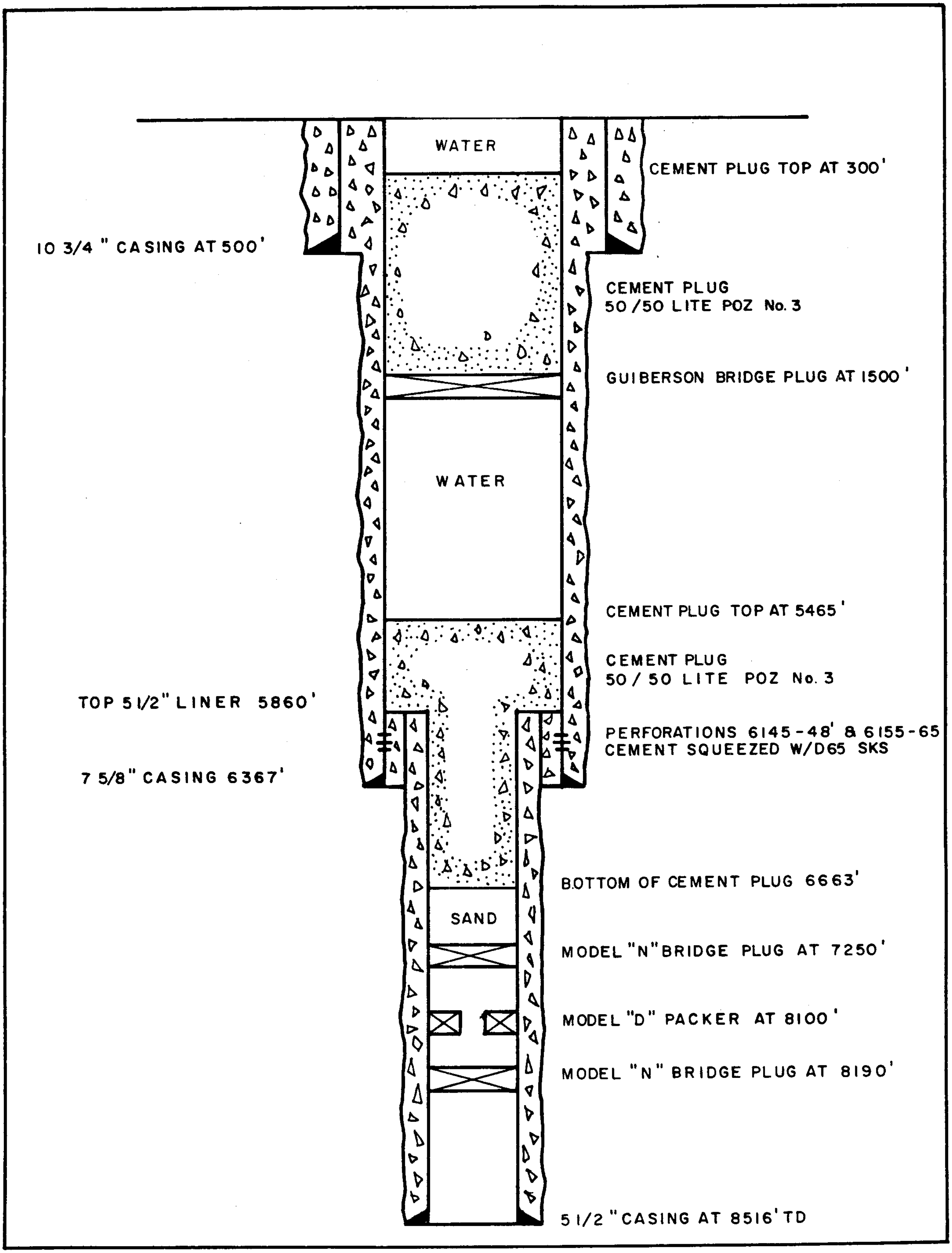
The R-EX Well has 7-5/8" casing set to a depth of 6367' and a 5-1/2" casing liner set in the interval 5860' to TD 8516'. The abandonment process employed in this hole consisted of setting a competent cement plug in the interval 5465 - 6663'. Water was placed inside the 7-5/8" casing from a depth of 5465' up to 1500' at which point a conventional bridge plug was set. From a depth of 1500' to a depth of 300' from the surface, a competent cement plug was placed and, from 300' to the surface, water was placed in the hole.

The Xmas tree, consisting of a 10-3/4" x 7-5/8" casinghead placed on the 10-3/4" casing, was used to suspend the 7-5/8" casing. This piece of equipment also includes a positive seal assembly between the 10-3/4" surface casing and the 7-5/8" protection casing. A tubing head with two 2" outlets was installed above the casinghead. The 2" outlets on the tubing head are presently blanked off. The upper portion of the tubing head has a blind flange with a 1/2" opening in which a valve and pressure gage have been installed, the purpose of which is simply to record or measure pressure, if any, and allow removal of pressure prior to reinstallation of additional Xmas tree equipment.

General Equipment Test Data

The tested pressure of equipment will be approximately twice the designed working pressure. The designed working pressure is the pressure at which the equipment may be operated at all times and at which it is believed there is no chance of failure because of pressure.

The minimum designed working pressure of all equipment (which could be exposed to the wellhead shut-in pressure) that is utilized in connection with the reentry drilling and/or completion and testing of the well, will be 3,000 psi. The minimum factory tested pressure of all this equipment is 6,000 psi. In each case, the manufacturer either has or will advise Austral of the designed working pressure and tested pressure of the equipment in accordance with the standards established by the American Petroleum Institute.



OBSTRUCTIONS LEFT IN HAYWARD 25-95 (R-EX)

FIGURE 4-1

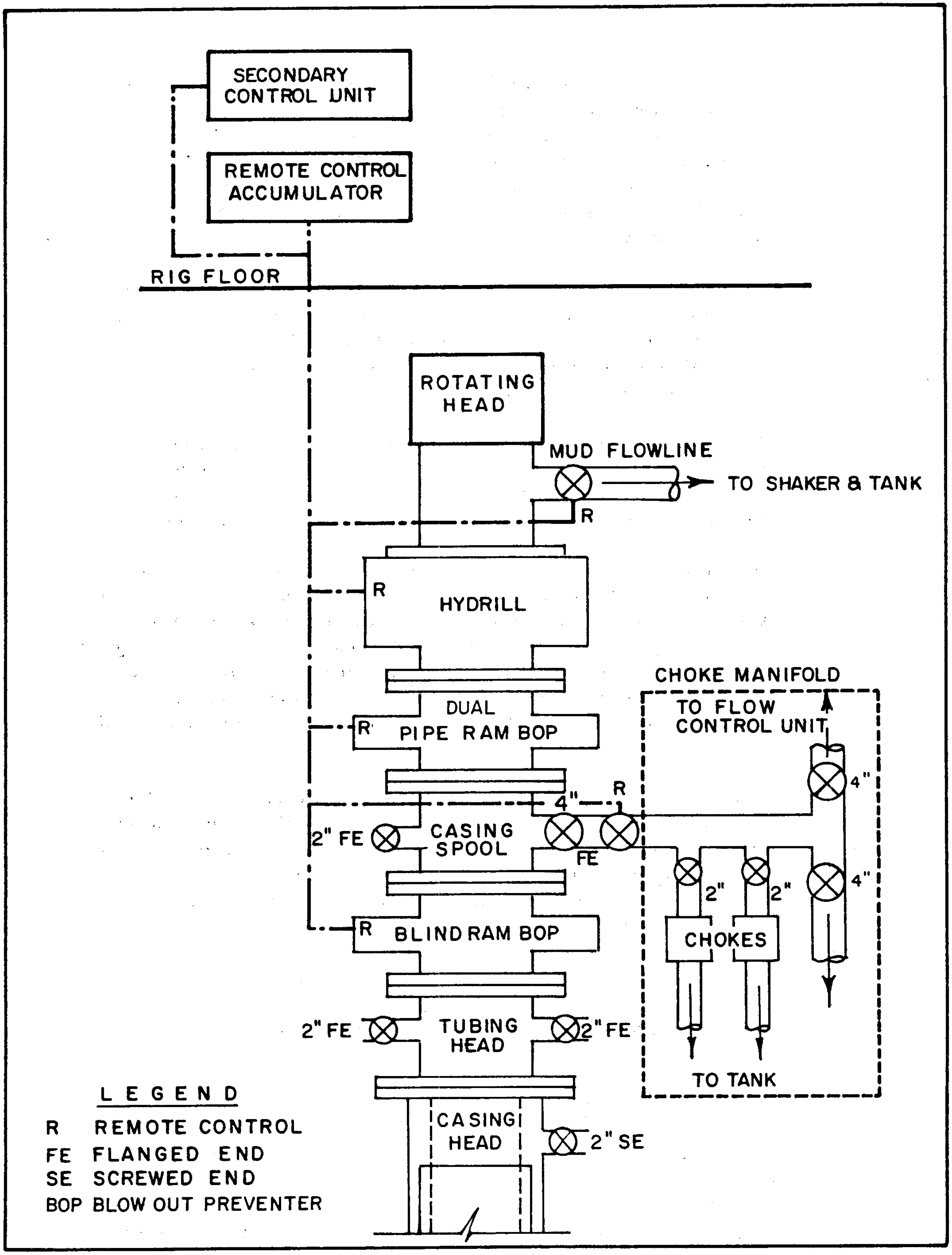
The American Petroleum Institute has established certain rules and regulations governing the methods by which these standards are achieved. Generally speaking, the largest factor in determining the working or tested pressure of equipment is the thickness of the steel utilized; however, with high pressure equipment the type of steel utilized becomes important. The general procedure followed in the petroleum industry is for the designed working pressure to be equal to or exceed the wellhead shut-in pressure.

It has previously been established through the pre-shot reservoir testing of R-EX that the static reservoir pressure is approximately 2930 psi, thus the maximum shut-in surface pressure will be no greater than 2600 psi. The minimum designed working pressure of the equipment that will be utilized in the various operations is 3000 psi. There is no situation under which the maximum shut-in surface pressure or flowing surface pressure can exceed the designed working pressure. Every piece of equipment which has or will be utilized which could possibly be exposed to such pressure in the various procedures concerned with the original completion and/or the future work, has a designed working pressure of 3000 psi and has actually been tested by the manufacturer. This equipment is conventional gas well equipment and has been used many times successfully.

Reentry Drilling Control Equipment

The drilling control equipment (Figure 4-2) which will be placed on the existing tubing head will meet the standards set by the American Petroleum Institute and will consist of the following:

> Valve assemblies will be reinstalled on the tubing head which is presently blanked off. Immediately above the tubing head will be installed a hydraulically controlled BOP in which blind rams will be installed, the purpose of which is to have positive shut-off control of the 7-5/8" casing below that point.
>
> Above the blind ram BOP will be located a casing pool (with comparable working pressure and test pressure) which will have two outlets on which valves will be installed for positive control. One of these will be a hydraulically controlled valve which can be operated remotely. Downstream of the hydraulically controlled valve will be installed a choke manifold which will allow complete control of the flow of liquids (mud returns) under pressure, if necessary. The liquids will be directed through a separation system or directly to the shale shaker or mud tanks. (Separator equipment will be described later.)



DRILLING CONTROL ASSEMBLY

FIGURE 4-2

Above the casing spool will be installed an additional BOP in which appropriate pipe rams will be installed which will be of the proper size to positively packoff around the drill pipe if desired. A dual-ram type BOP will be employed in this position during the use of the combination drill pipe string with the rams sized to packoff around both sizes, 3-1/2" and 2-3/4".

Immediately above this preventor will be located a Hydril preventor which also can be positively closed off around the drill pipe or, if necessary, can be completely closed when the drill pipe is withdrawn from the hole, under which circumstance it acts as a valve.

Above the Hydril will be located a flowline spool through which the mud returns can be directed to the shale shaker and mud tanks. The purpose of the shale shaker is to remove the cement or shale cuttings from the mud system.

Above the flowline spool will be located a rotating head which will control the flow of fluids while drilling such that there will be no escape to the drilling rig floor of either liquid or gas above this point. The rotating head is designed so that at all times there is a seal exerted around the drill pipe or kelly which circulates drilling fluids down the drill pipe and up the annular space through the conventional mud circulation system.

All preventor equipment and the hydraulic valves will be controlled by remote control and a hydraulic accumulator, the purpose of which is to allow the positive control of each of these pieces of equipment from either the drilling rig floor or a remote spot located a safe distance away from the rig location.

All valves and preventor equipment as well as the accumulator and remote control system will be tested to their working pressure (to assure continued reliability) as circumstances indicate that it would be desirable.

Drill String Assembly

The drill string assembly from the bottom of the string through the top will consist of the following and is outlined in general because each operational phase will require certain pieces of equipment unlike that which will be required for other phases. All equipment described herein will meet API standards and will be properly selected to meet drilling criteria. All equipment will be that which is conventional and similar to that which has been used many times before. No equipment used will be experimental in nature. All material used and procedures followed will be in compliance with the State of Colorado Oil and Gas Conservation Commission rules and regulations.

Appropriate drilling bit which may, as circumstances require, be 1) a tungsten carbide mill for removal of a certain portion of the casing liner, 2) conventional rock bit for drilling cement or formation, or 3) a diamond bit for drilling cement or formation.

Drill collars as circumstances require - the size of these will be dependent upon the hole size being drilled at any given time. The range of sizes will be from 3-1/2" to 4-3/4".

Two drill pipe floats which will allow fluid to be circulated down through the drill pipe but will not allow fluid to reenter from the opposite direction.

An "S" nipple - the purpose of which is to allow a positive plug to be set in the drill pipe if such is desired or required during drilling operations.

A 3-1/2" internal, flush modified, drill pipe (or a comparable type during the removal of cement from the 7-5/8" casing and milling of 5-1/2" liner), and a combination drill string consisting of the above described drill pipe together with a bottom section of drill pipe consisting of smaller drill pipe, i. e., 2-3/4" flush joint (during the remainder of drilling in the lower-most portion of the hole after setting the 5-1/2" liner in the sidetracked hole).

A safety valve to be located immediately below the kelly and at the uppermost portion of the drill pipe such that the kelly can be removed after closing the valve, if such is required.

Above the safety valve will be located the kelly, a hexagonal joint of pipe necessary for the rotation of the drill pipe. At the upper portion of the kelly will be a kelly cock. The purpose of the kelly cock is to allow a valve to be closed at the uppermost portion of the kelly so that the swivel and hook portion of the drilling equipment can be removed if it is desirable to do so while the kelly remains closed in.

Arrangements will also be made such that each of the valves and/or kelly cocks mentioned above can be pressure tested as often as circumstances require.

Reentry Procedure

After the installation of all the equipment has been made at the surface and all equipment has been amply tested in accordance with predetermined test requirements, the drill string assembly as described above will be inserted into the wellhead control equipment and drilling will commence in the cement at a depth of approximately 300'. The cement plug will be drilled from inside the 7-5/8" casing to a depth of 1500' and, subsequently, the bridge plug at 1500' will be drilled. The water in the interval 1500' - 5465' will become a part of the drilling fluid system. The cement in the interval 5465' to 5860' will then be drilled, after which the cement from the inside of the 5-1/2" casing liner will be drilled to a depth of approximately 6500'. After having removed the cement from the inside of the 5-1/2" casing, the casing liner hanger will be removed from the hole and the 5-1/2" casing will be milled out through the use of a pilot mill to a depth of approximately 6500'.

Prior to drilling the cement below the top of the 5-1/2" liner, the 7-5/8' casing will be calipered and pressure tested to determine its competency. After milling the 5-1/2" casing to a point just below the 7-5/8" casing, the 7-5/8" casing seat will be pressure tested to determine its integrity.

After milling the 5-1/2" casing liner to a depth of approximately 6500', a conventional whipstock (permanent) will be placed at the uppermost portion of the 5-1/2" casing liner at a depth of approximately 6500'. At this point, the whipstock will be oriented such that the hole to be drilled below that depth can be deviated in such a manner that it will eventually intersect the chimney of the R-E Well (emplacement hole) near the top. The exact bottom hole location of both the R-E Well and the R-EX Well is known from instrumentation used when the two wells were originally drilled. This data will be used in determining the exact direction and deviation required for the sidetrack operations. A hole, 6-3/4" in diameter, will be drilled below the whipstock point to a depth of approximately 7600' and a 5-1/2" casing liner will be set before drilling ahead. The casing point of 7600' is the objective depth; however, drilling conditions may require setting of the 5-1/2" liner at a shallower depth. After setting and cementing of the 5-1/2" casing liner, a portion of the previous drill string will be laid down and a smaller string of drill pipe as a stinger will be picked up and used in the inside of the 5-1/2" casing and for drilling below that depth.

Drilling below the 5-1/2" protection liner will proceed to the point where ample and adequate communication has been made with the chimney, and there is assurance of the ability to flow the well at high flow rates.

A conventional mud circulation system will be used. This system consists of pumping drilling fluid down the drill pipe and up the annular space between the drill pipe and casing or open hole. During the later course of this drilling it is anticipated that the mud drilling system will literally be lost in the cavity when adequate and complete communication has been attained. Thus, if any of the mud which has been used for drilling purposes has been contaminated with radioactive material, this radioactive mud will be permanently injected into the cavity.

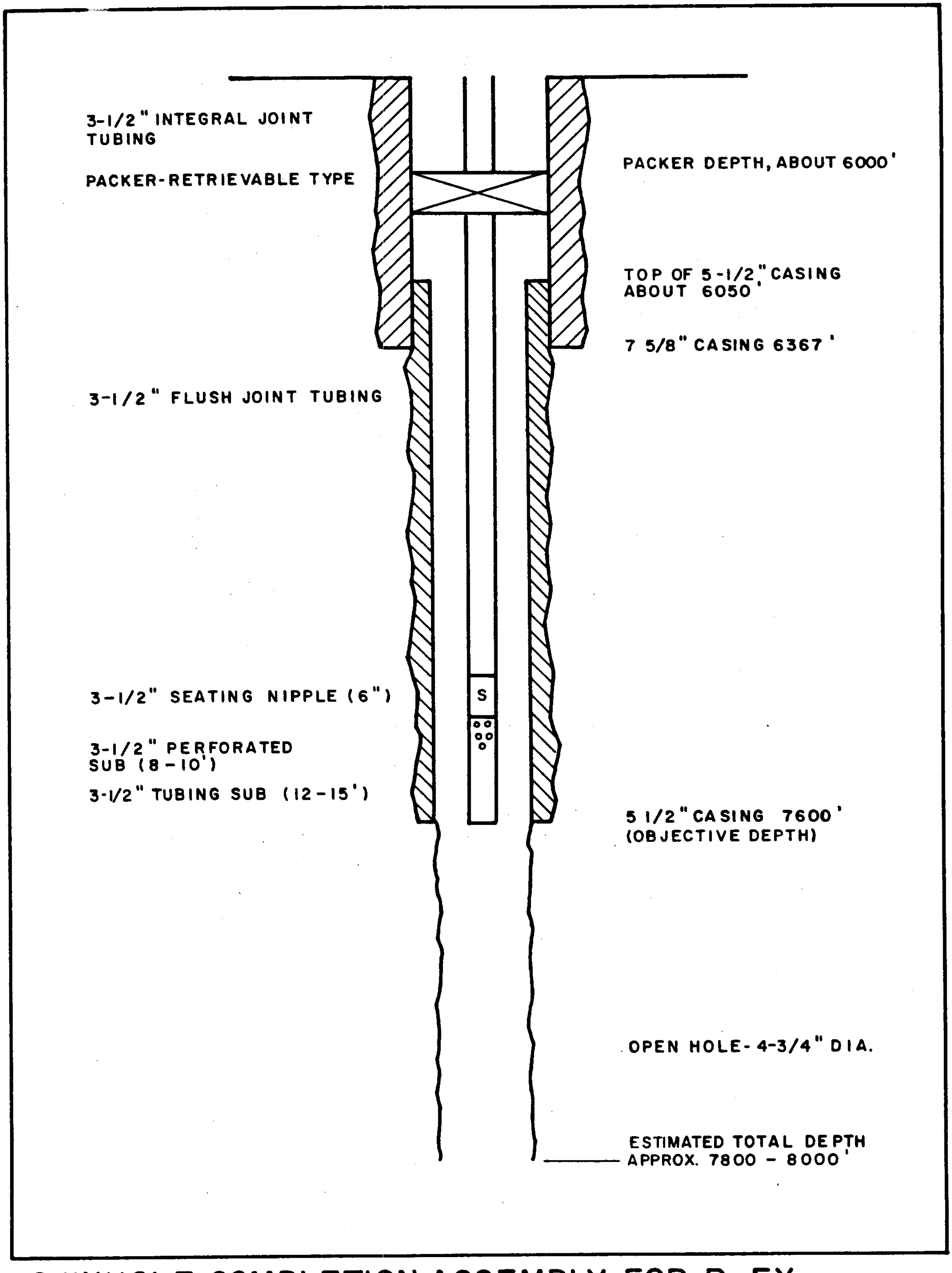
It is anticipated that when final and adequate communication has been made by drilling into the chimney, the drill pipe will be removed from the well under pressure controls which would allow no leakage of gas and/or drilling mud above the surface, and that a production tubing string and production packer would be installed in the well using similar procedures. Production tubing would be placed in such a manner that the casing annulus would be adequately sealed off. (Figure 4-3). The wellhead preventor hookup would then be removed and the permanent Xmas tree, a combination of flanges and valves and choke assemblies, placed on the wellhead for future production testing.

Additional Control and Safety Features

Flow Control — During early stages and for the greater part of the drilling operations, the mud discharge from the hole will pass through the flowline, over the shaker screen, and into the tank. It is expected, however, that during the later drilling, as gas cutting of the mud will reach an abnormally high level, provisions will be made for the controlled release of the gas-cut mud through the use of a flow control unit. A schematic diagram of this unit is shown as Figure 4-4.

The flow from the well is diverted through the appropriate manifold valve, shown on Figure 4-2, to the flow control unit. The stream first passes through an adjustable choke, where the back pressure is automatically controlled, and thence into a separator. The gas separates from the liquid phase and passes on to the flare stack. The fluid and cuttings are dumped back to the settling tank, where, relatively free of gas, the cuttings are removed by the shale shaker screen.

The inlet side of the flow control unit, from the choke manifold through the adjustable choke, will consist of equipment with a minimum working pressure of 3000 psi. Its integrity can be tested during the routine testing of the wellhead drilling control assembly and choke manifold.



DOWNHOLE COMPLETION ASSEMBLY FOR R-EX

FIGURE 4—3

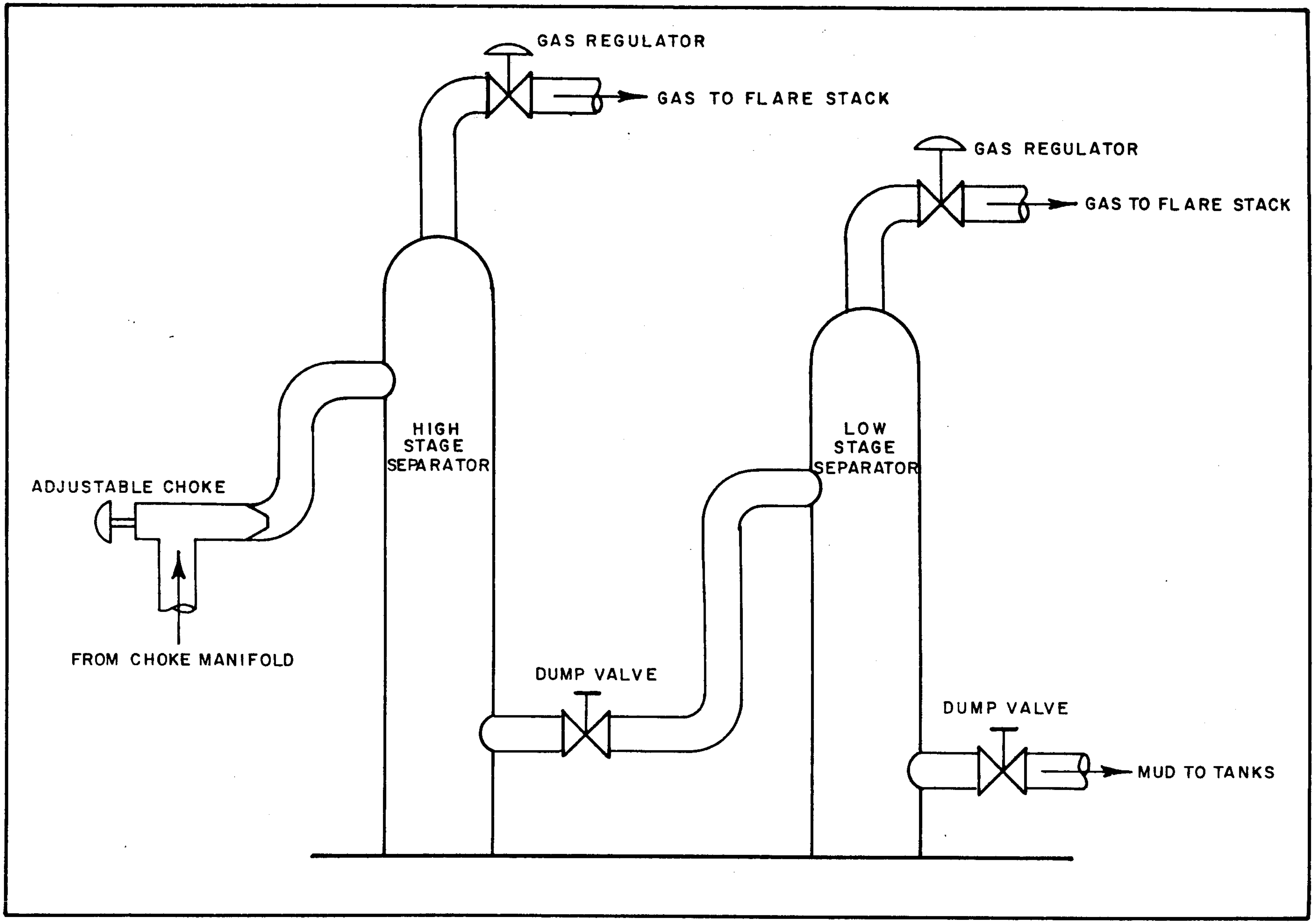


FIGURE 4-4

FLOW CONTROL UNIT

Ventilation System — The wellhead drilling control assembly will be enclosed and equipped with an air vent system (Figure 4-4). This enclosure will be sized to permit working room around the wellhead equipment and will have the air intakes sized to provide at least 100 linear ft/min. air velocity. In addition, the settling tank and shale shaker will be equipped with a hood and similarly ventilated. (Figure 4-5). The discharge from this sytem will also be made through the flare stack.

Provisions will be made to place contaminated drill cuttings, if any, into suitable closed containers for appropriate disposal.

5. RADIOACTIVE SPECIES WHICH MAY BE ENCOUNTERED DURING REENTRY

During reentry drilling, radioactivity may be encountered when the drill enters the cracked zone about the cavity. No particulate material is expected to reach the surface, as mud circulation will also be lost when cracks are encountered, and the particulate material will be flushed into the cavity with the lost drilling mud. Drilling will proceed from this point with lubrication provided by addition of drilling mud to replace that lost to the cavity. While drilling mud is circulating, it will be monitored at frequent intervals. It is possible that tritium contamination may appear in the mud before circulation is lost.

As the cavity is approached, the well will be pressurized by the reservoir gas. Drilling will continue with containment around the drill string. Any gas leaking from the drilling equipment will be drawn off with a shroud, and released through a stack to protect the drilling crew. The gas coming from the well is expected to contain radioactivity in the concentrations given in TABLE 5-1.

TABLE 5-1

CONCENTRATION OF RADIOACTIVITY IN THE GAS

(Calculated on basis of 1.29×10^7 M^3 gas volume at 10.8 psi, 0° C)

Isotope	Expected Concentration (μ Ci/cm^3)
^3H	8×10^{-4}
^{85}Kr	8×10^{-5}
^{14}C	4×10^{-10}

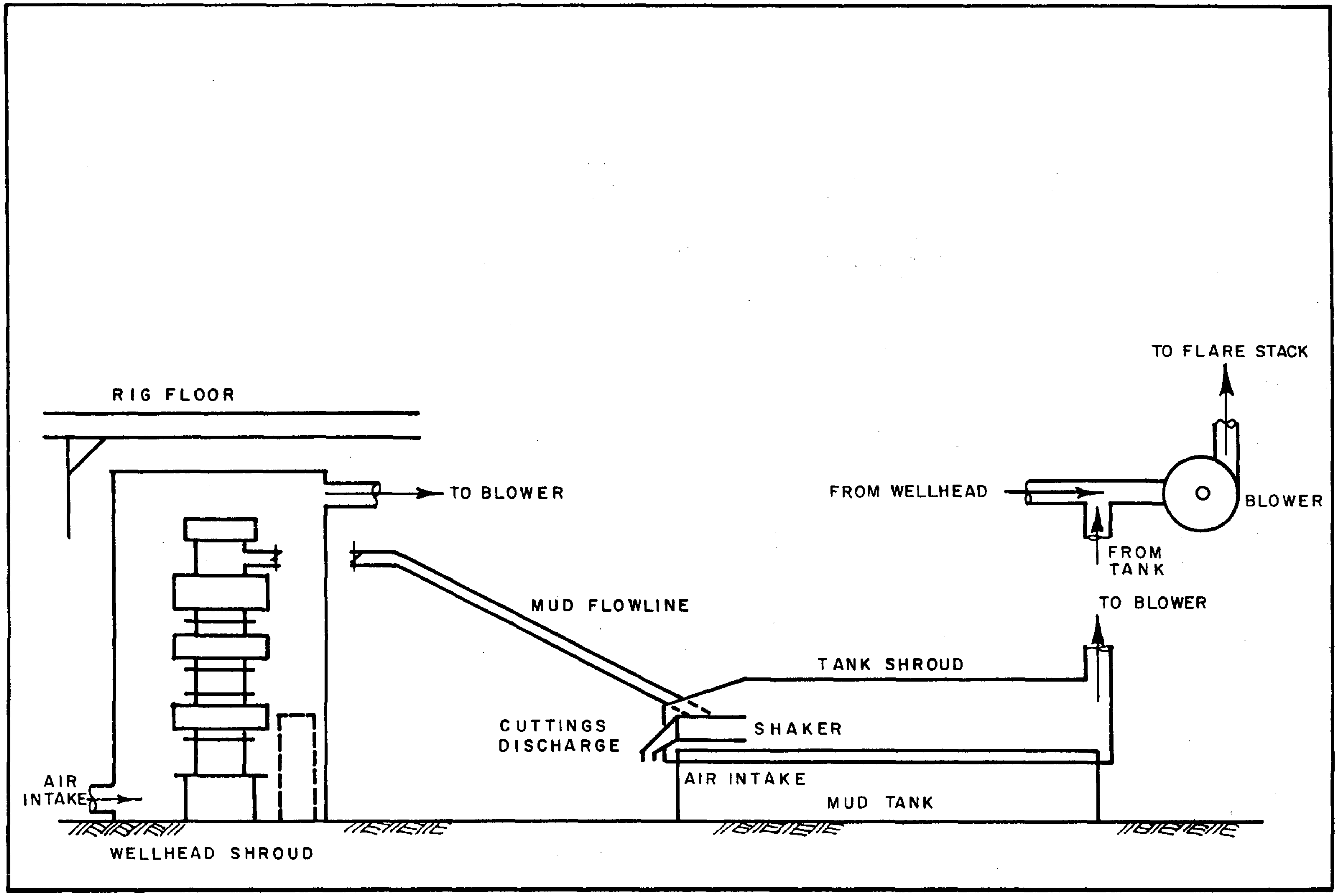


FIGURE 4-5

AIR VENT SYSTEM

6. PUBLIC SAFETY CONSIDERATIONS ARISING FROM RELEASE OF RADIOACTIVITY

Possible Routes to Public Exposure

Radioactive materials released from the RULISON cavity may contribute to public exposure through three routes. These are by 1) exposure to air containing radioactivity, 2) ingestion of radioactively contaminated water or 3) ingestion of radioactively contaminated foods.

Air

Entrapment of particulate material within the molten rock and rubble produced during the detonation and radiological decay since the detonation have reduced the amount of radioactivity in the RULISON cavity that could be released to a small fraction of that produced. The isotopes associated with the gas are expected to be those which are in gaseous form at the temperature of the cavity. These are tritium, ^{14}C, and the inert gases – krypton, xenon and argon.

Water

Radioactivity may be transported through the air with ultimate deposition on surrounding surface water supplies. The radioisotopes to be expected are: tritium in the form of water vapor, ^{85}Kr, ^{133}Xe, ^{37}A, ^{39}A, and ^{14}C. Some of this radioactivity may be incorporated into surface waters as a result of direct diffusion from the air or as a result of scrubbing of the radioactivity from an air mass by precipitation.

Food

The mechanisms which transport radioactivity directly to man can also serve to bring it into his environment where it becomes indirectly available through secondary routes. Perhaps the most common indirect pathway is through milk. Deposition of radioactivity on pasture or feed, and to a lesser extent by direct inhalation, may result in the secretion of a percentage of that radioactivity in milk. Meat animals may accumulate radioactivity in the tissue in the same manner.

The deposition of radioactivity on agricultural food crops provides another indirect pathway for the potential exposure of man.

Deposition on soil may make radioactive materials available for later uptake by plants during the growing season.

7. PROCEDURES TO ASSURE PUBLIC SAFETY

Operational procedures to assure compliance with established safety criteria are summarized as follows:

a. Tritium and krypton concentrations will be measured in the gas at the time of flaring. The types and amounts of other isotopes if present will be documented by appropriate sampling and analysis.

b. Meteorological support will be available to provide predictions of trajectories and concentrations of effluent. The Director of Nuclear Operations will use this information to determine that the operation may continue within established safety criteria.

c. Samples of air, water and food will be collected in populated areas and analyzed. From these analyses, radiation dose to the public will be calculated and action will be initiated, if necessary, to maintain compliance with the established safety criteria. (See p. vi).

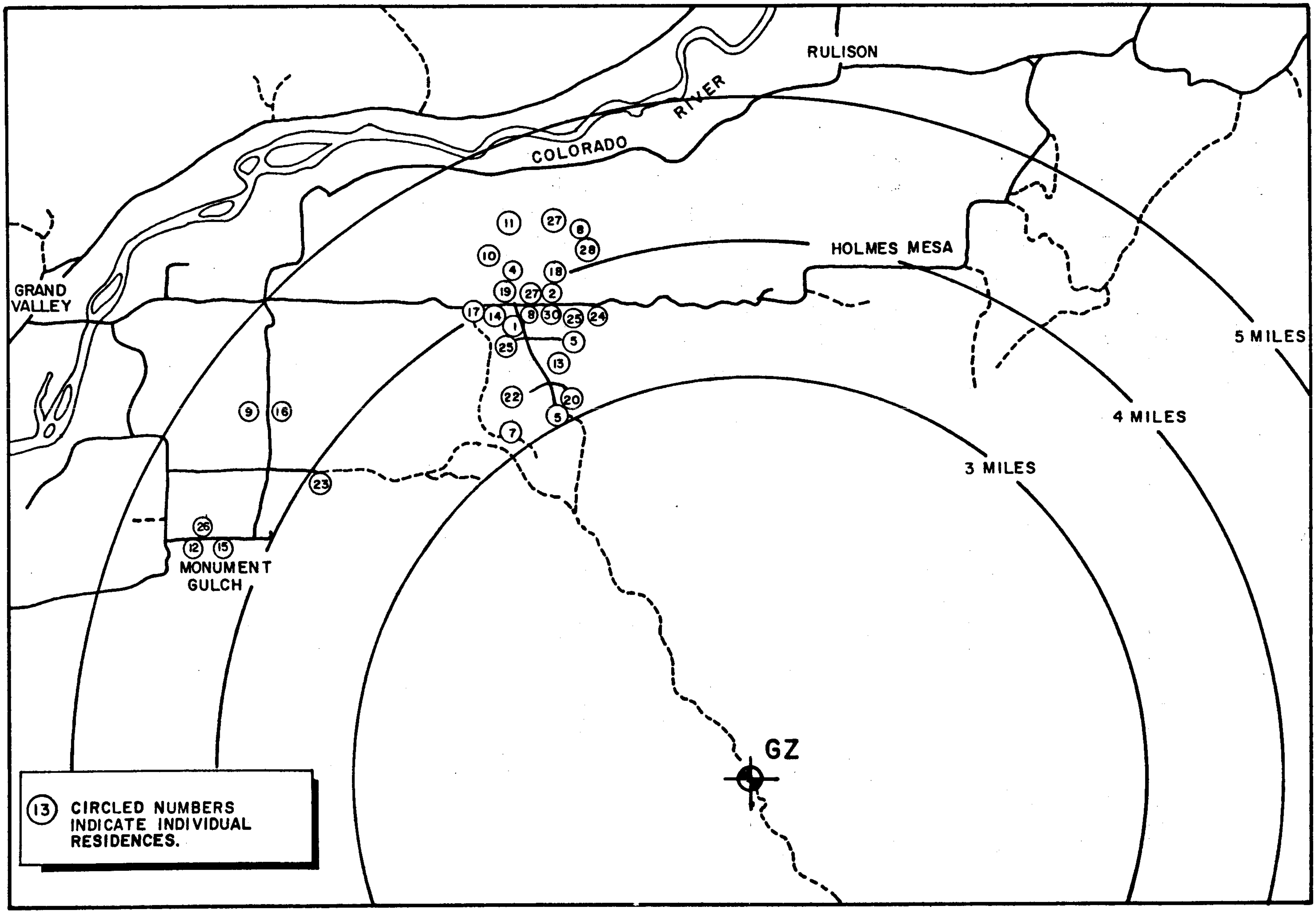
   Particular emphasis will be placed on surveillance of Battlement Creek water to assure the safety of the families using it. Figure 7-1 indicates the location of Battlement Creek water users and TABLE 7-1 indicates the water use.

d. Instruments and procedures to be used in assuring public safety are detailed in the following section.

8. RADIOLOGICAL SAFETY PLAN

This plan is intended to extend the Project RULISON Safety Plan issued for Project RULISON on August 15, 1969. Radiological control and monitoring procedures to be observed during reentry into the RULISON chimney and during the subsequent production testing by contractors and affiliated agencies will be as outlined below.

FIGURE 7-1



LOCATION OF BATTLEMENT CREEK WATER USERS

TABLE 7-1

BATTLEMENT CREEK WATER USERS

MAP NO.	HOUSEHOLD	GARDEN	ORCHARD	ALFALFA
1.	X	X		
2.	X	X	X	
	(Some truck garden sold)			
3.	X	X		
4.	X	X	X	
5.	X	X	X	
6.	X	X		
7.	X	X		X
8.	X	X	X	X
9.				X
10.	X	X	X	X
11.	X	X		
12.		X		X
13.	X	X	X	X
14.	X	X	X	X
15.	X	X		
16.	X	X		
17.	X	X	X	
18.	X	X		X
19.	X	X	X	X
20.	X	X	X	

TABLE 7-1 (Cont'd)

BATTLEMENT CREEK WATER USERS

MAP NO.	HOUSEHOLD	GARDEN	ORCHARD	ALFALFA
21.			X	
22.	X	X	X	X
23.	X	X		
24.	X		X	
25.	X		X	
26.	X	X		X
27.	X	X	X	
28.		X		
29.	X	X		
30.	X	X		

RADIOLOGICAL SAFETY (WORK AREA)

Responsibilities

Radiological safety responsibility within the work area will be delegated to the Operations Director (OD) by the Director of Nuclear Operations (DONO) during the reentry and initial flaring. When the OD assumes responsibility for radiological safety, he is responsible to the DONO to assure that the radiological safety program is conducted within criteria established for the work area.

Support

The Eberline Instrument Corporation (EIC) will provide radiological safety support services for the DONO and to the OD as required. Sufficient personnel will be provided to periodically monitor the drill rig as well as to operate an on-line gas monitoring system.

Personnel Monitoring

Personnel monitoring will be conducted as necessary by the use of individual personnel dosimeters and bioassays.

Sampling and Analysis

To ensure complete control of the situation in the work area, sampling and analysis to establish environmental factors will be conducted as directed by the OD. Such sampling will include, but will not necessarily be limited to the following:

> Air samples will be collected and analyzed for appropriate contaminants (e.g., particulates, vapors).
>
> Surface swipes will be taken routinely in all work areas to determine if contamination is present.

Control of Radioactive Sources and Contaminated Materials and Equipment:

The OD will establish procedures to ensure that all radioactive materials brought into the work area will be registered.

> Control of radioactive materials entails surveillance of the material during receipt, possession, transportation, use and storage.

The user scientific laboratory, agency or organization is responsible for notifying the EIC when receipt, movement or transfer of any radioactive material is to be initiated.

Materials or equipment which are to be removed from the area will be monitored, packaged and labeled in accordance with requirements of the Department of Transportation (DOT). Procedures for the removal of contaminated and/or radioactive material from the area will be established by the DONO to ensure compliance with all pertinent regulations and rulings.

Facilities and Equipment

Basic facilities which will be used in the working area to provide radiation monitoring services for the Project RULISON drillback are described below. The Access Control and Radiological Measurements facilities will be outfitted, moved to their operating location and put into a condition of operational readiness prior to initiation of drillback.

The Access Control Facility will be positioned at the entrance of the work area and will:

Provide a control point for access into the work area.

Provide a personnel monitoring and decontamination station for persons leaving the work area.

Serve as a facility for the issuance and return of personnel dosimetric devices, anti-contamination (Anti-C) clothing, and portable instruments for detecting radioactive material, explosive mixtures, and toxic gases.

Serve as a headquarters for radiation monitoring personnel.

The Radiological Measurements Facility will be equipped for analysis of air samples; for maintenance, calibration and test of monitoring equipment; for special process measurements (STALLKAT); and for a limited bioassay capability.

Decontamination — A steam-cleaning capability for equipment decontamination will be provided. Contaminated clothing will be laundered by a commercial decontamination laundry.

Drilling-Circulated Mud System

During this operation, the drilling control and containment gear, the shale shaker and settling tanks will be shrouded by suitable fixtures. The enclosures will be exhaust-ventilated at a rate to ensure in-flow of controlling air currents, i. e., a minimum of 100 linear feet per minute air velocity into all openings. Sufficient in-flow will be provided to keep the atmosphere in the enclosures below the lower explosive limits of the gas leaking from the containment system on off-gassing from recirculated mud. Enclosed places will be monitored by probes for explosive gas mixtures. Probes will be connected to a centrally located readout and alarm system.

The exhaust air will be vented to the atmosphere through a single stack. Monitoring of the exhaust stack will be accomplished in the following manner:

> The System to Analyze Low Levels of Krypton and Tritium (STALLKAT), and/or the U. S. Bureau of Mines type detection system, will be employed to continuously monitor this exhaust air stream for krypton and tritium. Grab samples of the air stream will be obtained to provide correcting factors for particulate and condensate fractions of the gas system.
>
> The exhaust stream will be sampled continuously for particulate matter, gases and water vapor. A minimum of one sample per 8-hour shift will be collected and analyzed. More frequent sampling will be accomplished as experience indicates.
>
> A sensitive gamma monitoring instrument will be utilized to record gross gamma radiation levels associated with the effluent passing through the stack.

Production Testing

Gas produced by the well in the production test period will be processed by a separator into three product streams, i. e., 1) gas stream, 2) water, and 3) condensate (hydrocarbon liquid comparable to a low-grade gasoline). All product streams will be discharged through a seventy-foot-high flare stack. The natural gas stream will be discharged directly through the stack; the water will be converted to steam and injected at the flare; and the condensate will be discharged into the stack. The various process streams will be monitored to determine the amount of radioactivity released to the atmosphere per unit time, as follows:

Main Gas Stream

The System to Analyze Low Levels of Krypton and Tritium (STALLKAT), and/or the U. S. Bureau of Mines type detection system, will obtain a sample of the main gas stream just before the stream enters the flaring stack. Samples will be analyzed at a minimum rate of one per hour.

Continuous sampling of the stack for particulates, gases and water vapor will be accomplished. Frequency of sample analysis will be dictated by experience and flow-through rate of the production gas, but will be no less than once each 8-hour shift.

Water Fraction

A representative sample of the water from the separator will be collected prior to discharging any volume increment of the water to the flare stack. The water will be analyzed for tritium and subjected to a gamma pulse height analysis. Suspended and dissolved solids in the water will be beta counted and subjected to gamma pulse height analysis.

Condensate Fraction

The condensate fraction will be oxidized and analyzed by the procedures outlined above for the water fraction.

RADIOLOGICAL SAFETY (PUBLIC)

Responsibilities

The Southwestern Radiological Health Laboratory (SWRHL), U. S. Public Health Service, is responsible to the Atomic Energy Commission for providing the Public Radiological Safety Program for Project RULISON, under the general direction of the Director of Nuclear Operations. The operational procedures which will be followed for the Public Radiological Safety Program during the reentry (drillback) and production testing or flaring phases of the project are outlined below.

SWRHL is responsible to the Director of Nuclear Operations for radiological services including the following:

Determine by fixed station and mobile monitoring and, if necessary, by aerial surveys, the extent of any contamination resulting from the operations.

Maintain a comprehensive record of public radiation monitoring data associated with the operation.

Ensure continuing protection of the public health, which will include the sampling of various types of environmental media such as air, water, milk, soil, vegetation and animal tissue, as required.

As requested by the Director of Nuclear Operations, investigate incidents that might possibly be attributed to the operation.

Program planning and field activities will be performed by the SWRHL Environmental Surveillance Program personnel. Colorado Department of Health officials have been consulted on the planning and will participate in the execution phases of the surveillance program. Field and support personnel will consist primarily of personnel from SWRHL, supplemented when possible by personnel from the Colorado Department of Health.

Surveillance Plan

The environmental surveillance plan for the drillback and flaring programs will consist of surface monitoring, supplemented with aerial monitoring as required. The intensity of the surveillance program during various phases will depend on such parameters as the initial surveillance results, flaring and radioactivity release rates, meteorological conditions, and productivity of foodstuffs in the area of concern during the time of the operations.

Surface monitoring will involve reestablishing SWRHL environmental surveillance networks operated in the RULISON area for the detonation period in 1969, and the operation of special-purpose manned sampling stations. The field personnel will be furnished with two-way radio equipped vehicles. Aerial monitoring may include tracking and sampling of gaseous releases with specially equipped SWRHL aircraft. The program will include collection of background samples prior to any release of radioactivity. These samples will include food and water used by selected wildlife, domestic livestock and humans. The emphasis will be on tritium levels, although levels of other fission and activation products will also be documented.

Throughout the first few days of flaring, an intensive special-purpose monitoring program will be conducted. This will entail manning monitoring stations and possibly aerial sampling systems positioned in accordance with meteorological guidance for both daytime lapse and nighttime drainage conditions.

Direct reading monitoring systems will be employed during certain periods in the drillback and flaring programs to assist in the timely assessment of radiological situations. These devices will include portable survey instruments to measure external radiation levels, and tritium and krypton measuring devices capable of detecting at least 10 microcuries of tritium per cubic meter of air.

Other monitoring activities are described below. (See TABLE 8-1.)

Air Sampling

The fifteen air sampling stations originally established for Project RULISON will be reactivated prior to initiation of the drillback procedure and operated through the initial flaring and as long as the radiological situation warrants. These samplers are equipped to collect continuous particulate filter and charcoal cartridge samples, and will be located at the populated locations and communities shown in Figure 8-1.

Approximately five of these stations, located in the predominantly downwind directions from the site, will also be equipped to collect atmospheric moisture samples for analysis for tritium.

Particulate samples will be collected beginning one week prior to initiation of reentry. Charcoal cartridge sample collection will begin prior to the beginning of reentry and continue as required to document any releases of radioactivity. Atmospheric moisture samples will be collected during the drillback and flaring phases of the program.

Four Air Surveillance Network stations from the 103-station SWRHL network in the western states are located at Durango, Grand Junction, Denver and Pueblo, Colorado. Data from these stations will be available in support of the drillback and flaring of Project RULISON. Samples from this network are collected daily.

Monitoring personnel will carry portable air samplers during drillback and flaring operations to supplement the fixed stations. These monitors will be equipped to collect particulate, gaseous and atmospheric moisture samples. Molecular sieves, silica gel, and/or cryogenic samplers will be used to collect samples for analysis of tritium, ^{14}C and ^{85}Kr.

TABLE 8-1

ANALYTICAL PROCEDURES - TECHNICAL SERVICES - SWRHL

Sample, Type	Analysis	Instrumentation	Count Length	Analytical Procedures	Detectable Limits	Notes
Air Filter						
a) Glass-Fiber	β	Low Background Wide Beta I	2 min.	Gross activity at time of count. Repeated counts for extrapolation to estimate activity at end of collection time.	Net counts exceed 4 times 2-Sigma counting error.	
	γ	Gamma Spectrometer	10 min.	8x8 Matrix solution. Selected isotopes specified in equations' solution.	0.1 pCi/m^3	50-100 pCi total in sample/isotope
b) Charcoal	γ	Gamma Spectrometer	10 min.	Gross count with warning limit set at 300 CPM above background over 0-2 MEV energy range. Isotopic analysis by 8x8 Matrix solution.	0.1 pCi/m^3 Single isotope	50-100 pCi total in sample/isotope
Milk	γ	Gamma Spectrometer	20-40 min.	Isotopic analysis by 8x8 Matrix solution.	20 pCi/m^3 ^{131}I 20 pCi/l ^{137}Cs 20 pCi/l ^{140}Ba-La	If masking occurs (presence of other isotopes) detectable limit will vary.
	^3H	Liquid Scint.	100 min.	Collect water distilled from Milk	0.4 pCi/ml H_2O	Based on minimum of 5 ml

TABLE 8-1 (Cont'd)

ANALYTICAL PROCEDURES - TECHNICAL SERVICES - SWRHL

Sample, Type	Analysis	Instrumentation	Count Length	Analytical Procedures	Detectable Limits	Notes
	^{89}Sr	Low Background Wide Beta II	50 min.	Chemical separation by ion-exchange method. Separated sample counted successively; activity calculated by simultaneous equation solution.	5 pCi/l	^{89}Sr, ^{90}Sr analysis dictated by presence of ^{131}I, or ^{140}Ba-La
	^{90}Sr	Low Background Wide Beta II	50 min.		2 pCi/l	
Water	γ	Gamma Spectrometer	20-40 min.	Isotopic analysis by 8x8 Matrix solution.	20 pCi/l	
	α	Wide Beta II	50 min.	Sample dried, gross activity calculated.	2 pCi/l	
	β	Wide Beta II	50 min.		2 pCi/l	
	^{89}Sr	Wide Beta II	50 min.	Chemical separation by ion-exchange. Separated sample counted successively; activity calculated by solution of simultaneous equations.	5 pCi/l	^{89}Sr, ^{90}Sr analysis dictated by presence of ^{131}I or ^{140}Ba-La
	^{90}Sr	Wide Beta II	50 min.		2 pCi/l	
	^{3}H	Liquid Scintillator	100 min.	Sample prepared by distillation. Counted in liquid scintillation counter.	400 pCi/l	

TABLE 8-1 (Cont'd)

ANALYTICAL PROCEDURES - TECHNICAL SERVICES - SWRHL

Sample, Type	Analysis	Instrumentation	Count Length	Analytical Procedures	Detectable Limits	Notes
Feed (Cow)	γ	Gamma Spectrometer	10-20 min.	Isotopic analysis by 8x8 Matrix solution.	50 pCi/kgm	
Vegetation	γ	Gamma Spectrometer	10 min.	Gross activity calculated. Qualitative analysis.		Quantitation only within order of magnitude for select isotopes.
	^{3}H	Liquid Scint.	100 min.	Separate water from vegetation.	0.4 pCi/ml water	Based on a minimum of 5 mls of moisture.
Air a) Grab	Xe & Kr β	Glass envelope Geiger counter	30 min.	Inert gases separated from air sample and beta counted. Xe & Kr activity concentration is calculated.	100 pCi total sample	0.3 m^3 usual sample size.
b) Molecular Sieve 1. Ambient	^{3}H & ^{4}C	Liquid scintillation counter	100 min.	Water and CO_2 removed from sieve and collected. Water analyzed for ^{3}H and CO_2 for ^{14}C by liquid scint. counting.	^{3}H 0.4 pCi/ml* H_2O ^{14}C 6 pCi/m^3 air	Based on a minimum of 5 mls moisture.
2. Cryogenic	^{3}H & ^{14}C	Liquid Scint.	100 min.	Water, CO_2 and noble gases removed from sieve, separated and collected. Water analyzed for ^{3}H and CO_2 for ^{14}C by liquid scintillation.	^{3}H 0.4 pCi/ml* H_2O ^{14}C 6 pCi/m^3 air	1.5-4.0 m^3 usual sample size

*1-8x10^3 pCi/m^3 air depending on relative humidity in anticipated range.

TABLE 8-1 (Cont'd)

ANALYTICAL PROCEDURES - TECHNICAL SERVICES - SWRHL

Sample, Type	Analysis	Instrumentation	Count Length	Analytical Procedures	Detectable Limits	Notes
Air 2. Cryogenic (Cont'd)	Xe & Kr	Glass envelope Geiger counter		Xe & Kr fractions beta counted in glass envelope Geiger counter.	Xe & Kr 100 pCi total sample	
c) Freezeout	^{3}H	Liquid Scintillation counter	100 min.	Air passed over cold trap to freeze out moisture. Water analyzed for tritium.	^{3}H 0.4 pCi/ml* H_2O	3-6 liters per minute sampling rate. Sample size varies.
Natural Gas	Rn	Rn-Alpha Scintillation counting	60 min.	Rn-direct transfer to Alpha scintillation cell and counting.	Rn-0.04 pCi/l	100 ml Alpha scintillation cell.
	^{3}H & ^{14}C	Liquid Scintillation counting	100 min.	Gas is combusted and noble gases, water and CO_2 are separated.	20 pCi/l (^{14}C) 1 pCi/l (^{3}H)	About 4-1 burned
	Xe & Kr	Glass envelope Geiger counter	30 min.		100 pCi Total Sample 100 pCi Total Sample	About 12-1 Burned.
Animal, Wildlife, Vegetation & Soil	^{3}H	Liquid Scintillator	100min.	Prepared by distillation of H_2O from sample	.4 pCi/ml of H_2O	Detectable limits based on minimum of 5 ml of H_2O
Animal & Wildlife	γ	Gamma Spectrometer	20-40 min.	Isotopic analysis by 8 x 8 matrix solution	50 pCi/Kg	Various animal organs analyzed separately
	^{89}Sr	Low Background Wide Beta II	50min.	Chemical separation by ion-exchange	5 pCi/sample	Usually only done on bone sample
	^{90}Sr	Low Background Wide Beta II	50 min.	Chemical separation by ion-exchange	2 pCi/sample	Usually only done on bone sample

TABLE 8-1 (Cont'd)

ANALYTICAL PROCEDURES - TECHNICAL SERVICES - SWRHL

Sample, Type	Analysis	Instrumentation	Count Length	Analytical Procedures	Detectable Limits	Notes
Soil	γ	Gamma Spectrometer	10-40 min.	Qualitative Analysis		Quantitative analysis not usually performed because of U and Th in soil.
	^{89}Sr	Low Background Wide Beta II	50 min.	Leach Sr from soil. Chemical separation by ion-exchange.	5 pCi/sample	
	^{90}Sr	Low Background Wide Beta II	50 min.	Leach Sr from soil. Chemical separation by ion-exchange.	2 pCi/sample	

Descriptions can be found in Document NVO-28, USAEC Publication, Revised 1968.

Detailed procedures are presented in "SWRHL Analytical Procedures Manual" SWRHL.

Instrumentation Description:
a) Gamma Spectrometer; 4" x 4" NaI(Tl) detector, 200 channels calibrated at 10 kev (channel detector enclosed in a steel box with 6"-thick walls, with lead, cadmium and copper lining).

b) Wide Beta I, pure methane gas flow, 4" hemispherical detector with anti-coincidence guard ring and automatic sample changer with 60 sample capacity.

c) Wide Beta II, pure methane gas flow, 2" hemispherical detector with anti-coincidence guard ring and automatic sample changer with 80 sample capacity.

d) Liquid Scintillation Counter. Ambient temperature.

* 1-8 x 10^3 pCi/m^3 air depending on relative humidity in anticipated range.

NOTE: Detectable limit for ^{14}C in air (Air b) based on assumption of 0.03% CO_2 in Air.

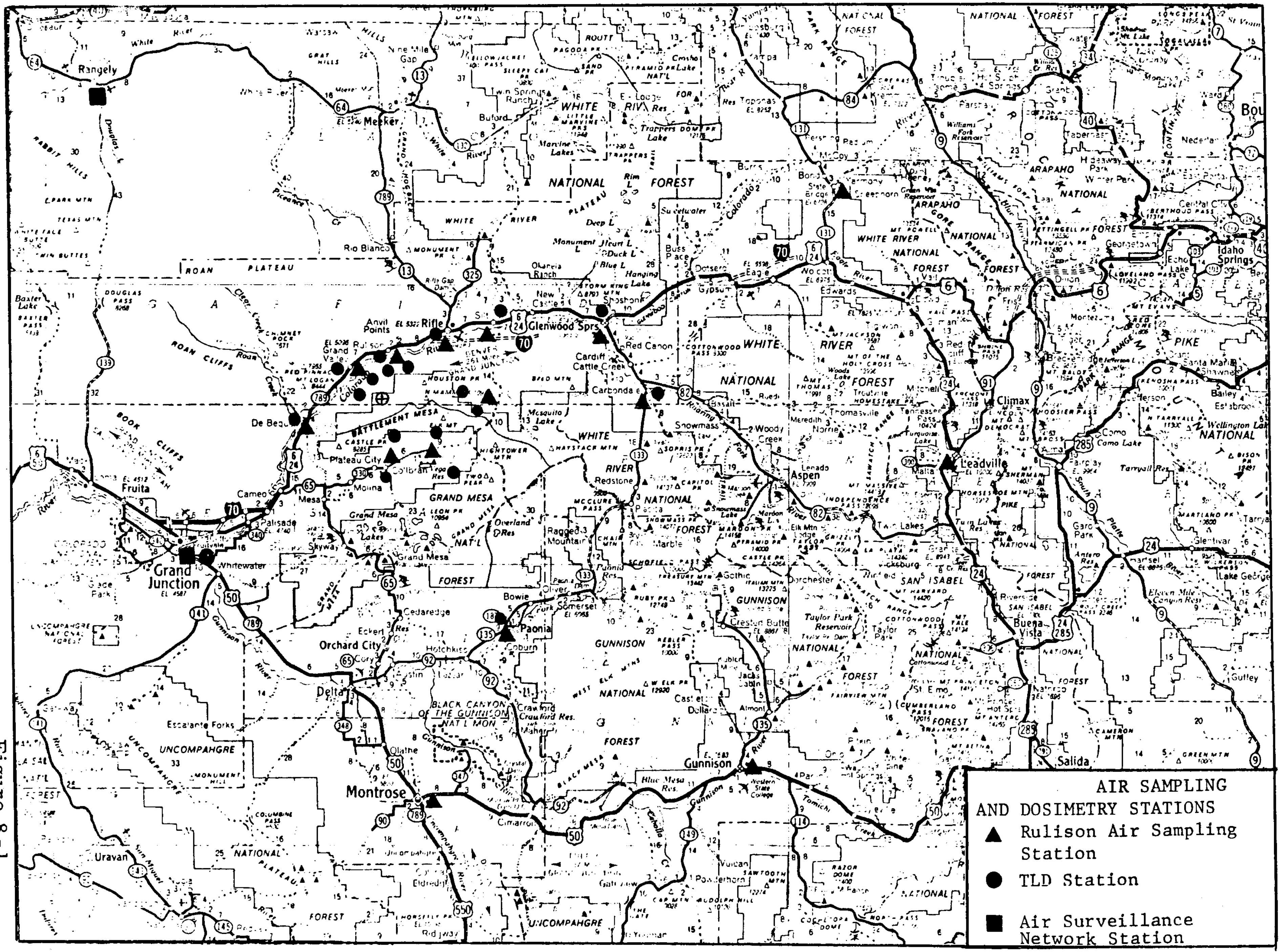

AIR SAMPLING AND DOSIMETRY STATIONS
Rulison Air Sampling Station
TLD Station
Air Surveillance Network Station
Rangely
Meeker
Rifle
Glenwood Sprs
Grand Junction
Fruita
Delta
Montrose
Paonia
Gunnison
Aspen
Leadville
Climax
Buena Vista
Salida
Idaho Springs
Uravan
Orchard City
Cedaredge
Collbran
Plateau City
De Beque
Grand Valley
Rulison
Carbondale
BATTLEMENT MESA
GRAND MESA
WHITE RIVER NATIONAL FOREST
GUNNISON NATIONAL FOREST
UNCOMPAHGRE
ARAPAHO NATIONAL FOREST
PIKE NATIONAL FOREST
SAN ISABEL

Figure 8-1

Dosimetry

Eight thermoluminescent dosimeter (TLD) stations will be established prior to drillback in a five-mile circular array around the site. Twelve additional TLD stations will be located at the air sampling locations listed below and shown in Figure 8-1. Additional TLD stations will be established in the immediate area of the site.

DeBeque	Collbran
Grand Valley	Carbondale
Rulison	Paonia
Rifle	Silt Mesa
Silt	Mesa
Glenwood Springs	Grand Junction

Each thermoluminescent dosimeter station will be equipped with three EG&G TL-12 thermoluminescent CaF_2:Mn dosimeters with a sensitivity range from 5mR to 5,000 R. These devices will be placed at the respective stations one week preceding the beginning of drillback and exchanged and read at monthly intervals until the operation is completed.

During drillback and flaring, monitors will carry additional TLD's for issue to residents and for supplemental uses. These TLD's will be collected at intervals and returned to Las Vegas for reading.

Milk Sampling

The SWRHL Standby Milk Surveillance stations in Colorado and other western states will be sampled as necessary. Standby stations in Colorado are located at:

Craig	Colorado Springs
Fort Collins	Durango
Glenwood Springs	Monte Vista
Grand Junction	Alamosa
Delta	Rocky Ford
Salida	

The SWRHL Rulison Milk Surveillance Network consists of five Grade A dairies and ten family milk cow locations shown in Figure 8-2. The Grade A dairies are:

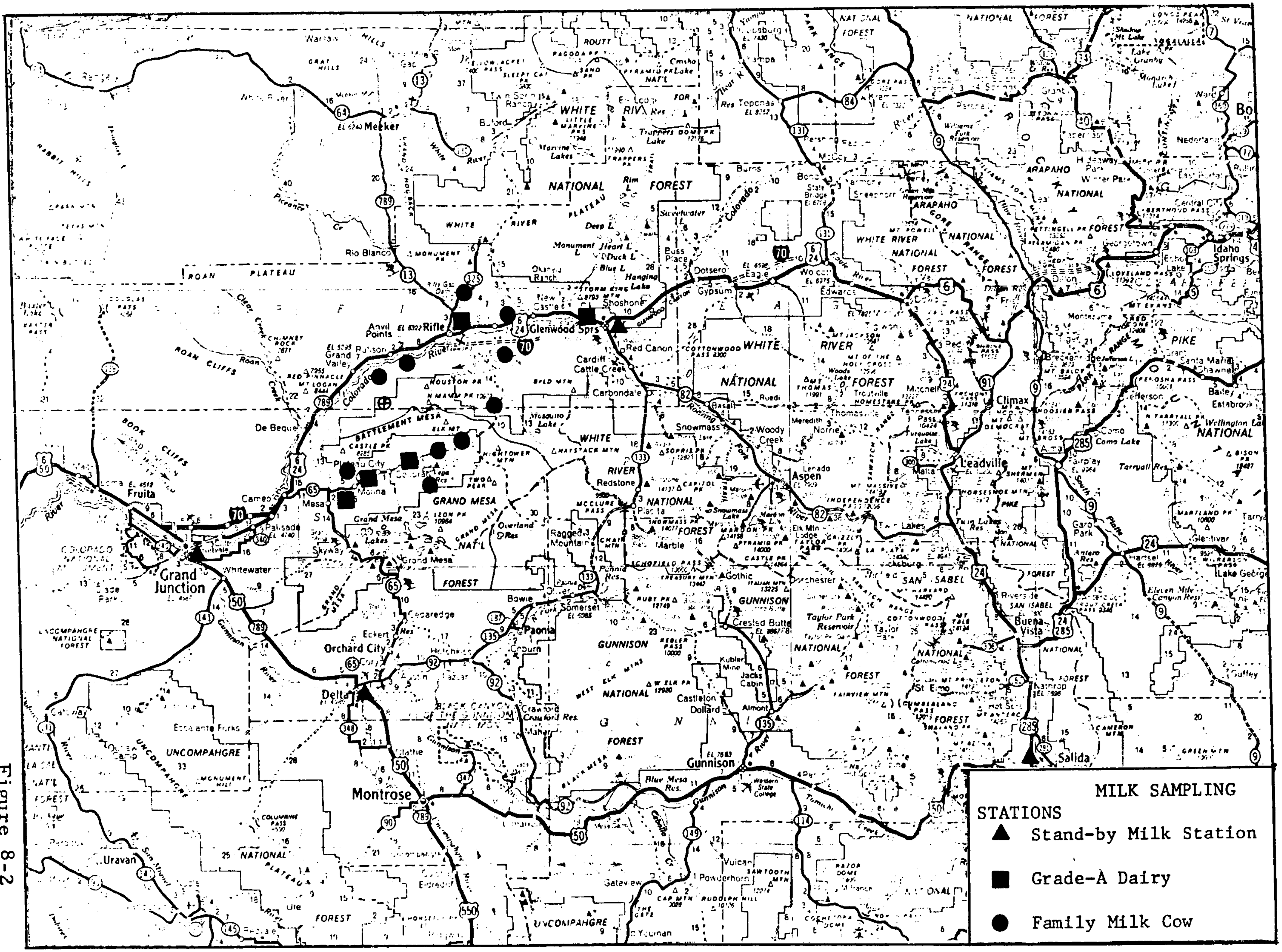

MILK SAMPLING
STATIONS
Stand-by Milk Station
Grade-A Dairy
Family Milk Cow
Meeker
Rio Blanco
Rifle
Glenwood Sprs
Grand Junction
Fruita
Palisade
De Beque
Delta
Montrose
Gunnison
Aspen
Leadville
Climax
Salida
Buena Vista
Paonia
Carbondale
Redstone
Marble
Crested Butte
Eagle
Gypsum
Dotsero
Orchard City
Cedaredge
Grand Mesa
Collbran
Mesa
Molina
Uravan
GRAND MESA
WHITE RIVER NATIONAL FOREST
GUNNISON NATIONAL FOREST
UNCOMPAHGRE
ROAN PLATEAU
BOOK CLIFFS
BATTLEMENT MESA

Figure 8-2

Alex Urguhart Dairy, Rifle
Rockin Pines Dairy, Molina
Cecil Young Dairy, Collbran
Rupert Wasson Dairy, Mesa
Glen Taylor Dairy, Molina

Milk samples will be collected at all stations during the week preceding drillback operations. Samples will continue to be collected at regular intervals throughout the drillback and flaring operations as necessary. Information on location of all family milk cows within 10 miles will be updated and selected locations sampled prior to and during the operation as necessary. Selected samples, primarily those nearest the site, will be analyzed for tritium in addition to gamma emitting radionuclides and radiostrontium.

Water Sampling

The SWRHL Rulison Water Surveillance Network will be reactivated for the post-event operations. The network stations consist of:

Twelve municipal supplies within 25 miles of the RULISON site, plus municipal supplies at Glenwood Springs, Carbondale, Paonia, Cedaredge and Redstone.

Five private wells in the area immediately surrounding the site, and a special well on Battlement Creek near the USGS gauging station above Morrisania Mesa.

Three springs in the area immediately surrounding the site.

Four Reservoirs -

Vega Reservoir, near Collbran
Harvey Gap Reservoir, 6 miles north of Silt
Two representative reservoirs in the Grand Mesa area

Nine Streams -

Battlement Creek - daily samples just below the site and on Morrisania Mesa
Plateau Creek - 1 mile south of Collbran
Wallace Creek - Wallace Creek School
Cache Creek - intersection with Holmes Mesa Road
Parachute Creek - Grand Valley

Buzzard Creek - 6-1/4 miles east, 1/2 mile north of Collbran
Mamm Creek - Rifle Airport
West Divide Creek - Fairview
Colorado River - DeBeque

Water samples will be collected during the week preceding drillback and periodically throughout the flaring procedure as necessary. Figure 8-3 shows the location of water sampling stations.

In addition to the network described, a detailed survey of springs, streams, reservoirs and water supplies within 10 miles of the test well will be conducted, and selected stations will be established for sampling through the post-event operation, as required.

Snow samples from various locations in the RULISON area will be collected to document background and post-event radioactivity concentrations. Portable precipitation samplers will be deployed to collect samples of precipitation that may occur during drillback and flaring operations.

Animal and Wildlife Sampling

Specimens will be taken from deer in the RULISON area prior to drillback, and at intervals during and after operational activities at the RULISON site. Selected organs will be analyzed for mixed fission products and tritium. If necessary, as determined from other surveillance results, special samples of domestic animals and wildlife will be obtained.

Vegetation and Soil Sampling

Vegetation samples will be collected from stations around the RULISON site. Collections will be made prior to drillback, during flaring, and after testing is complete. Seasonal variation will be considered in selecting vegetation species, and special samples of appropriate fruits and vegetables will be collected.

Soil samples will be collected from representative vegetation sampling sites.

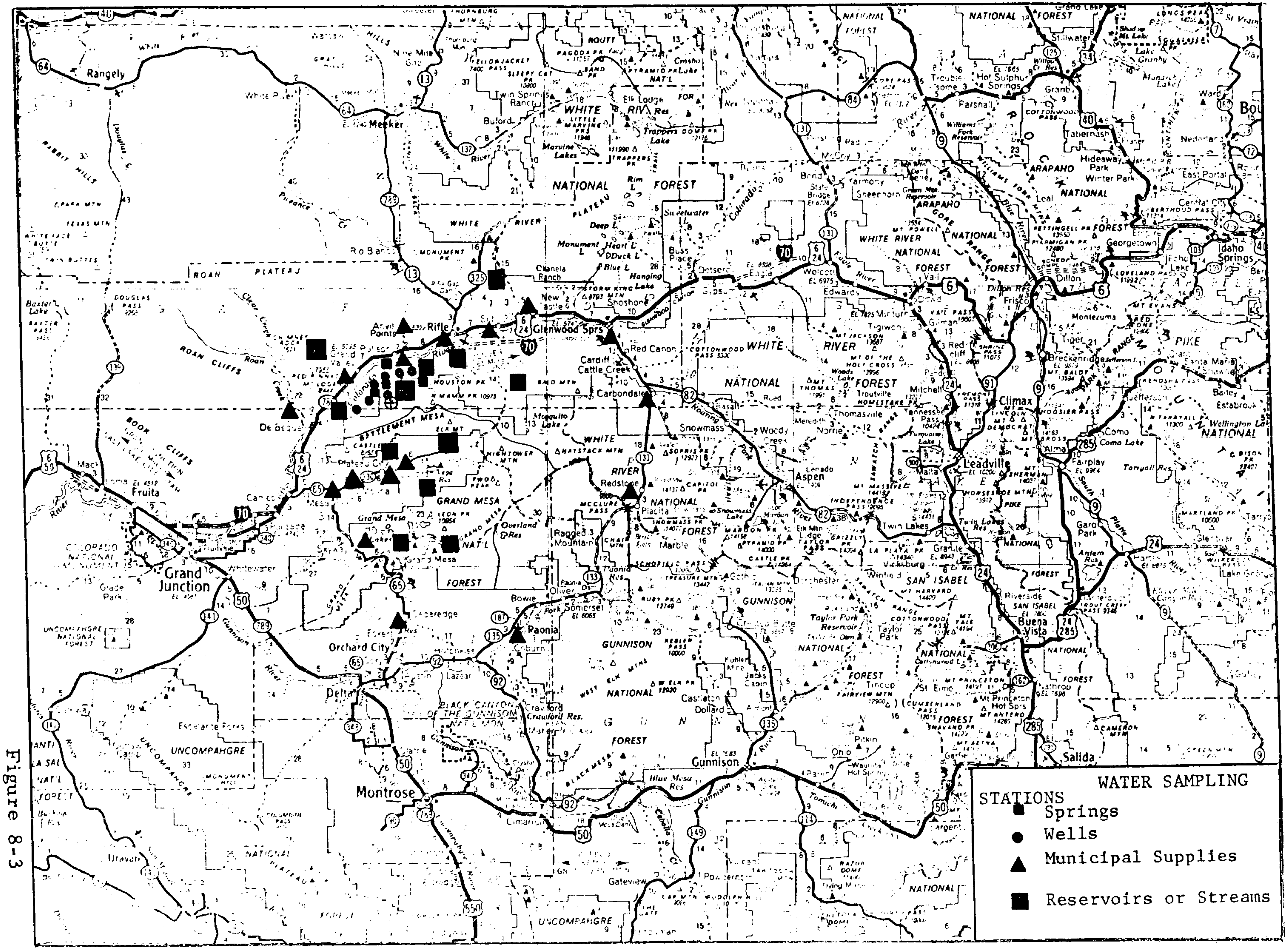

WATER SAMPLING
STATIONS
Springs
Wells
Municipal Supplies
Reservoirs or Streams
Rangely
Meeker
Rifle
Glenwood Sprs
Carbondale
Aspen
Leadville
Climax
Buena Vista
Salida
Gunnison
Montrose
Delta
Grand Junction
Fruita
Paonia
Orchard City
Grand Mesa
GRAND MESA
WHITE RIVER NATIONAL FOREST
GUNNISON NATIONAL FOREST
UNCOMPAHGRE
ROAN PLATEAU
ROAN CLIFFS
BOOK CLIFFS
De Beque
Parachute
Silt
New Castle
Redstone
Marble
Somerset
Twin Lakes
Granite
Alma
Fairplay
Breckenridge
Dillon
Vail
Frisco
Georgetown
Idaho Springs
Granby
Tabernash
Kremmling
Wolcott
Edwards
Minturn
Basalt
Snowmass
Crawford
Hotchkiss
Cedaredge
Cimarron
Blue Mesa Res.
Pitkin
Ohio
Almont
Nathrop
Garo
Como

Figure 8-3

Gas Sampling

Grab samples of natural gas will be collected from the RULISON reentry drill hole as soon as gas begins to flow. These samples will be collected in evacuated high-pressure steel bottles at the wellhead, using line pressure to fill the bottles. Filled bottles will be analyzed for radioactive constituents. After initial collection, grab samples will be collected at the wellhead whenever the line monitor indicates a significant change in radioactivity concentrations in the natural gas. Samples will also be taken of the condensate and moisture separated from the gas.

The initial samples will serve to determine the release rate of the radioactive nuclides, and will aid in establishing the calibration accuracy of the line monitor. The samples will be analyzed for tritium, ^{14}C, ^{85}Kr, Xe and other radioactive materials.

If it is determined that aerial monitoring is necessary, a SWRHL aircraft will be used to provide aerial sampling of effluent plumes. The aircraft may be used to provide information on plume rise, direction of transport, rate of movement, and the extent of diffusion. The aircraft may also be used to supplement ground surveillance by collecting low altitude samples in areas inaccessible to mobile monitors. Samples will be collected to determine particulate and radioactive gas activities. Cryogenic samples will be taken for ^{85}Kr, ^{14}C, and tritium analysis. The aircraft will also provide a means for rapid transportation of samples to SWRHL for analysis.

METEOROLOGICAL SUPPORT PLAN

Responsibilities

The Air Resources Laboratory, Las Vegas, Nevada, (ARL-LV) is responsible to the Atomic Energy Commission for providing forecasts of meteorological conditions and predictions of radiation movement and dispersion, under the general direction of the Director of Nuclear Operations.

The principal meteorological problem anticipated during the drilling reentry of the RULISON chimney and the flaring of the natural gas consists of knowing at all times the atmospheric trajectory and dilution and the forecasted deposition patterns of any radioactive gas released into the air. This information will be used by the Director of Nuclear Operations (DONO) to position radiation monitors, take environmental samples, and to exercise controls.

Objectives

The objectives are:

Design and emplace a meterological data acquisition network in the local area.

Provide weather data and weather forecasting service in support of the Director of Nuclear Operations safety programs.

Provide predictions of the dispersion of radioactive effluent that might result from Project RULISON activities.

To accomplish these objectives, ARL-LV will provide 24-hour weather forecasting and observing service as required by the Director of Nuclear Operations (DONO). ARL-LV will establish a forward area forecasting and observing complex near Surface Ground Zero (SGZ).

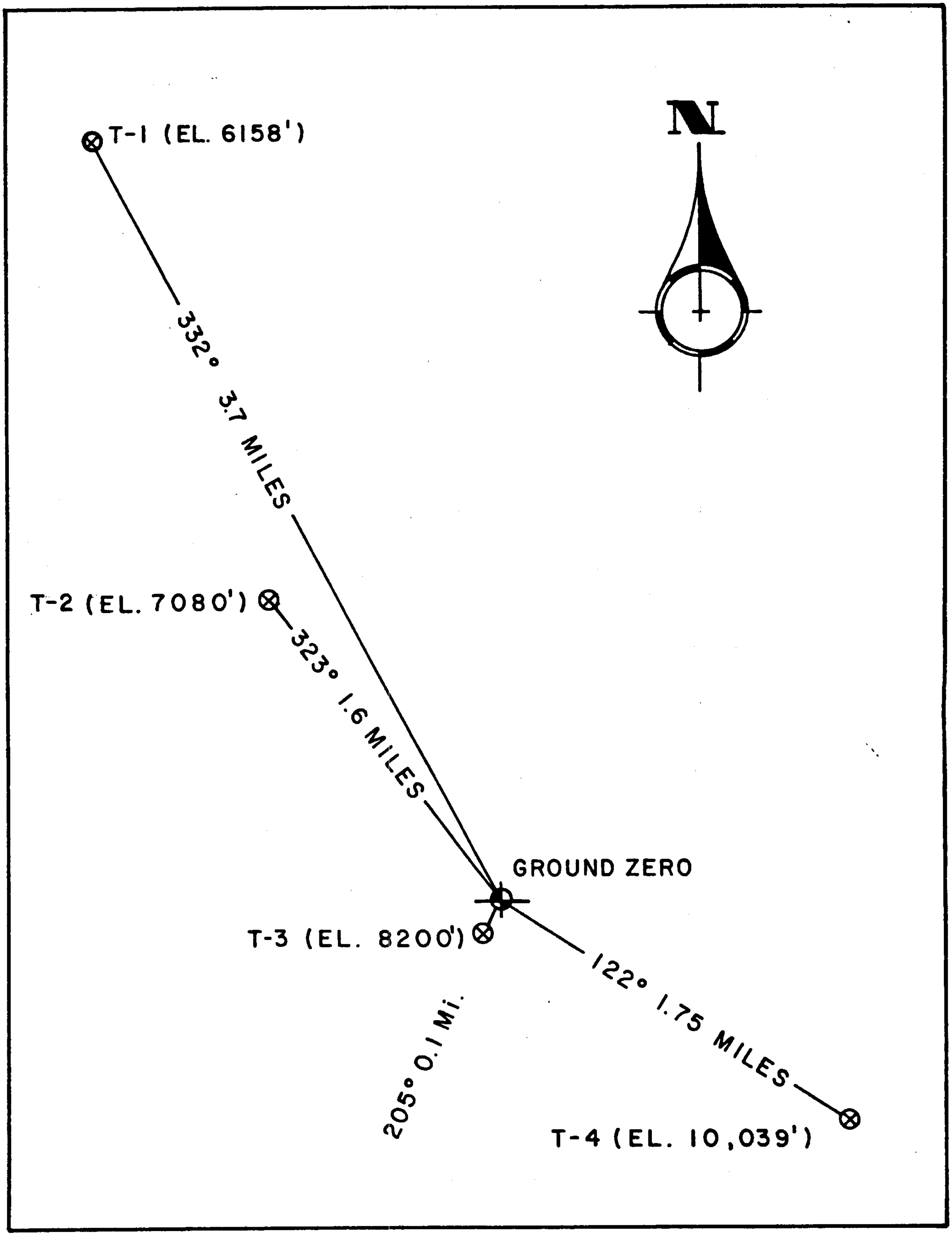
Instrumentation

The ARL-LV inflation van will be used as the primary observation point. Additional trailer space will be used for a weather forecasting office at the site. Both of these facilities will be near SGZ.

Maximum use will be made of the data from the National Weather Network available to the meteorologist in Grand Junction. To provide mesoscale forecasts for the RULISON area, the instrumentation required is as follows:

Surface Wind

The SYSTRAC radio-telemetered system will be used to obtain surface wind speed and direction at: Tower No. 1, 3.7 miles northwest of GZ; Tower No. 2, 1.6 miles northwest of GZ; and Tower No. 3, near GZ. (See Figure 8-4). Data from these stations will be telemetered into a master station in the inflation van. An electromechanical surface wind system will be installed at the wellhead as backup for Tower No. 3. The readout will be on an analog recorder located in the inflation van.



RULISON WIND TOWERS

FIGURE 8-4

Wind data from these towers will be continuously recorded and will provide the meteorologist a means of determining the local wind regime in the vicinity of the RULISON site. These data are also required to recommend placement of manned sampling stations.

Temperature and Humidity

Surface temperatures and relative humidities will be available from a hygrothermograph exposed in a standard instrument shelter located near the inflation van.

Upper Level Winds

The upper level winds will be obtained near the CP by pilot balloon observations (pibals) using a single theodolite. Additional mobile pilot balloon units will be available from NTS if the need arises.

The data will give an indication of the initial lateral dispersion of the effluent and, if required, will give indication where aerial sampling should begin.

Vertical Soundings

ARL-LV Ground Meteorological Device (GMD) will be used to obtain vertical temperature, humidity and wind soundings. The GMD will be located approximately 4 miles northwest of SGZ near Battlement Creek.

Vertical temperature soundings will be required to determine the on-site current atmospheric stability profile, estimates of plume rise height and can be used to obtain upper level wind observations during inclement weather (low ceilings). Upper-air soundings will also be available from the Grand Junction Weather Bureau Station.

APPENDIX A

MAXIMUM HYPOTHETICAL ACCIDENT

1. Postulation of the Maximum Hypothetical Accident

In order to assess the potential hazard (if any) that may result from an accidental loss of control over the gas flow during reentry or production testing, a maximum hypothetical accident was postulated though it is extremely unlikely that such a hypothetical accident could occur. The chance of a sudden and complete discharge of essentially all gaseous radionuclides from the chimney is regarded by the petroleum engineers who have examined the reentry plan as not only improbable but practically impossible. Nevertheless, to complete the analysis of radiological hazards, a study has been made to determine the effect of such an event.

2. Airborne Radioactivity Estimates

For the maximum hypothetical accident, it is assumed that an uncontrolled blowout occurs through an open drill hole, releasing 94% of the gaseous radioactive nuclides present at 180 days from detonation, over a 24-hour period.(1) (It should be noted that, based on the GASBUGGY experience, one would expect that only 10% of the gaseous radionuclides would be released. The initial sample analysis will indicate whether the available fraction for release is nearer 94% or 10%.) The total inventory of gaseous radionuclides present at 180 days after detonation is as follows:(1)

Nuclide	Curies
^{85}Kr	9.6×10^{2}
^{133}Xe	8.6×10^{-4}
^{37}A	1×10^{2}
^{39}A	2×10^{1}
^{14}C	1×10^{-1}
^{3}H	1×10^{4}

The released methane gas will be burned and the plume rise, due to its momentum and buoyancy, will be significant. Calculations indicate that the effective release height, as used in the diffusion calculations, will be 300 meters or more.[2] Estimates have been prepared for a 100 meter, a 300 meter, and a 600 meter daytime effective release height to demonstrate the effect of this parameter. A 600 meter height is not used for the nighttime case since this height is normally above the nocturnal surface inversion. The plume would be transported by the winds above the inversion and would not diffuse to ground level until the nocturnal surface inversion had been destroyed by solar heating.

Climatological wind data from the RULISON site indicate that air drains down-canyon during the nighttime and predominantly blows in a different direction during the daytime. Therefore, trajectories of airborne radioactivity released during the daytime and nighttime are expected to be different. For this reason the total release has been divided into a 12-hour daytime release and a 12-hour nighttime release with half of the total inventory being released during each period. The trajectory of air motion at night would be rather constant and the plume would have little meander. During the 12-hour daytime period, considerable meandering of the plume is likely to occur. Therefore, estimates of total integrated exposure (TIC) for the daytime period are considered conservative, since it has been assumed the plume travels along a constant trajectory during the entire period.

For the diffusion calculations, daytime atmospheric conditions were assumed to correspond to the Pasquill[3] stability category C (slightly unstable) with a mean wind speed of 5 mps. Nighttime conditions were assumed to correspond to the Pasquill stability category E (stable) with a mean wind speed of 3 mps.

3. Environmental Pathways of Radionuclides to Man

Radionuclides released to the surrounding ecosystem in the event of a hypothetical accident as described above may be transferred to humans by various environmental pathways. Some of these may be quite direct, e.g., external exposure and inhalation exposure to airborne radioactivity or ingestion of drinking water which has absorbed radionuclides. Other environmental pathways are somewhat less direct and, in fact, may involve multiple steps. Knowledge of the general character of the environment and land use patterns in the RULISON site area affords a basis for selecting those pathways that could be most significant in transferring radionuclides to man; three particular routes appear to merit discussion. Consider that during the hypothetical accident a quantity of the radionuclides enumerated above is released to the atmosphere and dispersed according to the prevailing meteorological regime. A fraction of the airborne radionuclides will be intercepted by, and retained on, vegetation--cultivated and natural. This vegetable matter (leafy vegetables, fruit) may in turn be consumed by humans. Other plant material (hay, pasture grass or native forage) may be eaten by herbivores such as cattle, deer or elk, which in turn are consumed by humans. Or, finally, humans may consume milk produced by milk cows feeding on vegetation that has intercepted airborne radionuclides. These three modes are believed to be the most significant ones for transporting airborne radionuclides through food chains to man in the particular environmental setting of Project RULISON.

More elaborate environmental transfer modes can be visualized. However, taking into account the local ecology and reasonable assumptions concerning the kinds of radionuclides that may be released, there is no reason to believe that such more complex pathways would lead to higher internal doses to man than the three routes specified above.

Near the RULISON site, the local human population utilizes locally grown garden vegetables and fruits, consumes meat from local range livestock and native herbivores (principally deer, plus a few elk), and uses milk from local cows. Therefore, consideration has been given to the potential internal radiation dose to man that might result from consumption of plant products that have intercepted airborne radionuclides accidentally released to the environment. Similarly, doses to man that might result from consumption of milk or meat products from primary herbivores feeding on such plant material are considered.

4. Estimation of Dose to Man From Radionuclides in Air

The applicable radiation protection guides for RULISON for an average annual dose or dose commitment to a suitable sample of the exposed population is 0.17 rem. The estimated dose resulting from the maximum hypothetical accident case, based on concentration of each nuclide, has been calculated as a function of downwind distance and the total dose is obtained by a summation of these individual contributions. It is expressed in Figure A-1 as a fraction of the 0.17 rem. It is apparent from this figure that, even using the 100 meter effective release height, the total dose which could result from the calculated air concentration is a small fraction of the 0.17 rem guide, for both the daytime and nighttime conditions.

5. Estimation of Dose Via Drinking Water

Two possibilities have been considered for estimating concentrations of radioactivity in drinking water resulting from reentry drilling:

a. If the leakage into the aquifer is in the form of radioactive gas, the radioactivity is expected to be confined in the immediate vicinity of the explosion site. If the leakage is in the form of radioactive water and confined to Mesa Verde formation rock, drill stem pressure tests show that there is no significant upward or downward potential for flow, but rather flow in these rocks will be lateral. Ground water in the Mesa Verde formation will flow in the fracture and primary pore spaces resulting in extremely low average water velocity. Therefore, radionuclide transport is expected to be very limited and the concentration of any nuclide in water is expected to be below 1 RCG beyond a thousand meters from the explosion site.

   If leakage in the form of radioactive water is into shallow water-bearing rock, water flow rate will be higher than in Mesa Verde formation. However, concentrations of radionuclides will be less than 1 RCG by the time these nuclides have traveled a few thousand meters and before they reach locations where the water might be used for domestic purposes.

b. For case two, radioactivity in surface water resulting from rainout of released radioactive gases could, if the gas were vented during rainfall and that rainwater subsequently used to fill cisterns, result in concentrations above those specified by AEC MC 0524[4] for continuous drinking water consumption. Although such an occurrence appears exceedingly remote, the planned water sampling program would lead to appropriate steps being taken to alert against such use of this water.

6. Estimating Radiation Dose Via Foods

a. The estimation of potential internal radiation dose to man via food chains is based on a general model which, given the radioisotopes source term and atmospheric dispersion predictions, can be used to estimate:

   (1) The interception and retention of airborne radionuclides by vegetation,

(2) The concentrations (as a function of time after release) of radionuclides in the organs and tissues of animals feeding on vegetation that has intercepted airborne radionuclides,

(3) The internal radiation doses to man that would result from his consumption of given quantities of tissue from such animals or vegetation or milk from cows feeding on the vegetation.

b. Not all of the biological and ecological constants required for application of the general model are available; as a consequence, certain of these have been inferred on the basis of the best data available. The assumptions used in making the present estimates are as follows:

(1) Estimates of internal radiation doses to man are based on tritium only. (Preliminary calculations show that the quantity and kind of other radioisotopes expected to be released would not contribute significantly to internal doses.)

(2) Tritium release to the environment will be in the form of tritiated water vapor, i. e., the gas released will be burned.

(3) Two cases of foliar deposition of tritiated water vapor are considered:

(a) "dry" deposition (i. e., when no precipitation is occurring)

(b) deposition during a 12-hour period of rain at the rate of 0. 5 mm per hour. [5]

(4) For estimating deposition and retention of tritium on vegetation, the following assumptions are used:

(a) a deposition velocity of 1 cm/sec

(b) the fraction of radioactivity intercepted by vegetation is 0.1

(c) the effective half-time on vegetation is 28 days for the dry deposition case and the effective half-time on vegetation is estimated to be about 2 days for the rainfall case.

(5) Transpiration and uptake from the soil (where the other 90 percent of the tritium is deposited) are considered for the rainfall case. The transpiration rate is taken to be 0.05 cm per day.

(6) For estimating the first year internal radiation dose to humans from consumption of vegetables and fruits that have intercepted airborne tritium, the following assumptions are used:

(a) 50 percent of the tritium is removed by washing or during preparation of the plant material for eating.

(b) 50 percent of the individual adult's caloric intake is derived from locally grown vegetables and fruits (this approximates 770 gm per day) over the entire period of one year.

(7) For estimating the first year internal radiation dose to human adults from consuming flesh of herbivores which have fed on vegetation that has intercepted airborne tritium, the following assumptions are used:

(a) the deposition and retention of tritium on vegetation is estimated on the basis of assumptions (1) - (4), para. 6.b., above.

(b) the animal derives its entire caloric intake from this vegetation; a 75 kg animal is assumed to consume 15 kg per day.

(c) the animal's effective bio-elimination half-time is 5 days.

(d) the animal is butchered at the time when the tritium content in its tissues reaches a maximum.

(e) man consumes 2 kg/week of the herbivore flesh throughout the year.

(8) For estimating the internal radiation dose to a human adult or child from consumption of milk from a cow feeding on vegetation that has intercepted airborne tritium, the following assumptions are used:

(a) The deposition and retention of tritium on vegetation is estimated on the basis of assumptions (1) - (4), para. 6.b., above.

(b) the cow's forage intake is about 40 kg/day for a 450 kg cow.

(c) the cow's bio-elimination half-time is approximately 3 days.

(d) the adult or child consumes 1000 gm/day of milk, at a tritium concentration assumed to be equal to that of the body water of the cow.

(e) the weight of the adult is 70 kg; that of the child is 10 kg.

(f) the bio-elimination half-time for adult and child is proportional to body weight to the 0.25 power; the half-time is 12 days for the adult and 7.4 days for the child.

c. Using the above assumptions, estimated doses to man from food lead to values from about 4 millirem for the dry deposition case to an extreme upper value of about 100 millirem per year for the rainout case. This upper value would only occur from the highly improbable simultaneous occurrence of an uncontrolled venting and rainout.

7. Summary

The foregoing discussion indicates that potential radiation doses to the nearest residents resulting from concentrations of radioactivity from air on locally produced foods, even in the postulated maximum hypothetical accident case, would be small compared to 0.17 rem/yr.

Control of exposure from drinking water supplies, which may be replenished during a simultaneous occurrence of the maximum hypothetical accident and rainfall, requires monitoring, sampling, and preventive action to assure that cisterns are not filled during such a time.

Remedial action capability will assure that the post-shot program can be carried out within the constraints of AEC MC 0524.

REFERENCES

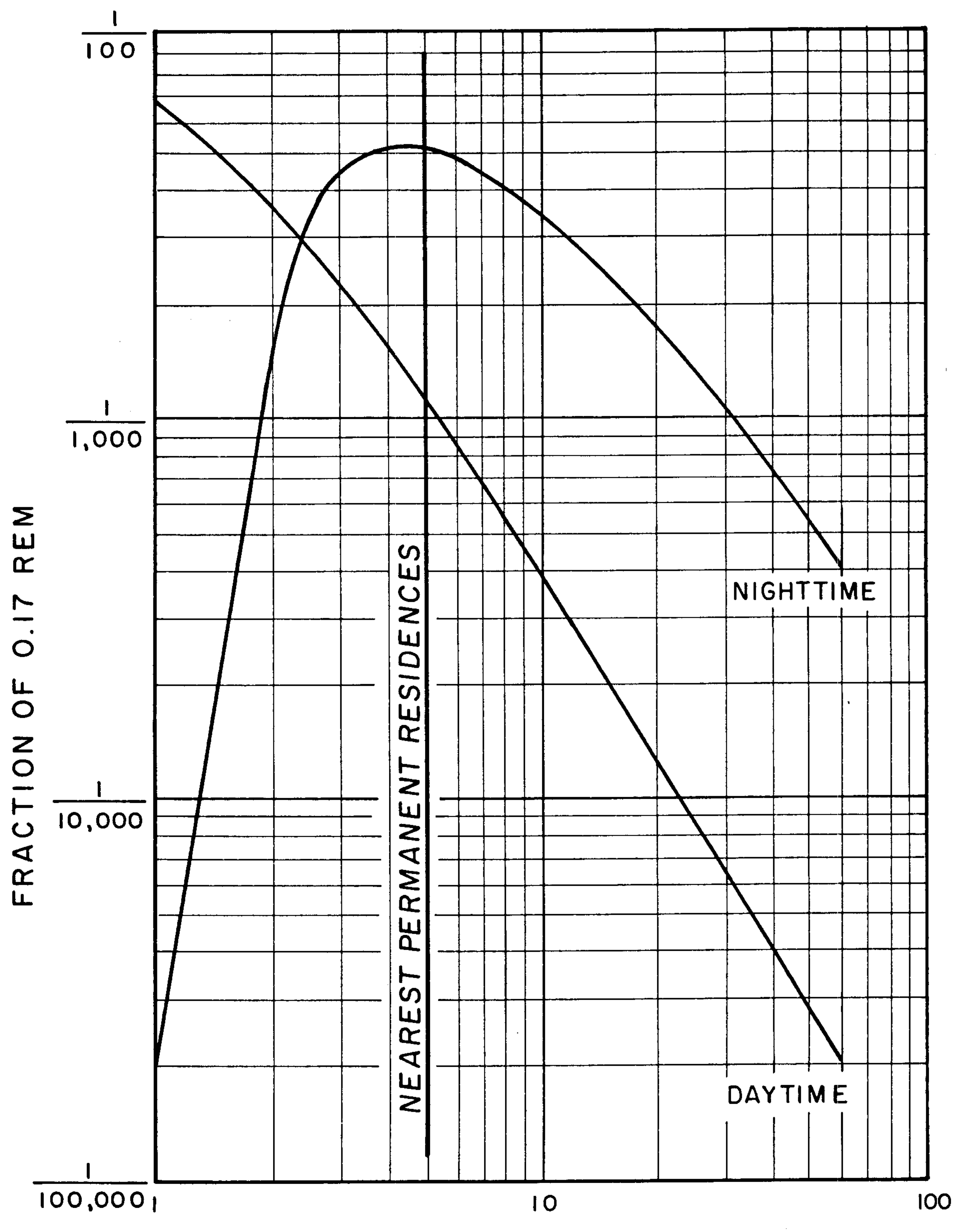
(1) Aamodt, R. L., Preliminary Outline of RULISON Re-entry Document, October 25, 1969.

(2) Briggs, G. A., Prediction of Plume Rise Heights, to be published in proceedings of 8th annual Environmental and Water Resources Eng. Conf., Vanderbilt Univ. School of Engineering, Nashville, Tennessee, June 1969.

(3) Pasquill, F., The Estimation of the Dispersion of Windborne Material, Meteorological Magazine, Vol 90, 1961.

(4) AEC Manual, Chapter 0524, Standards for Radiation Protection.

(5) Chamberlain, A. C., and A. Eggleton, Washout of Tritiated Water Vapor by Rain, Int. J. Air Water Poll., 1964, Vol 8, 135-149.



TOTAL DOSE RESULTING FROM EXPOSURE TO AIRBORNE RADIONUCLIDES FOR THE MAXIMUM HYPOTHETICAL ACCIDENT

FIGURE A-1

APPENDIX B

ECOLOGICAL CONSIDERATIONS*

A. SITE DESCRIPTION

1. Topography

Project RULISON Ground Zero (GZ) is located on the East Fork of Battlement Creek, a few hundred feet east of the main Battlement Creek and separated from the latter by a low ridge. Both forks of Battlement Creek lie in a narrow, V-shaped valley that heads at the edge of Battlement Mesa about 2 miles southeast of GZ. About 2-1/2 miles northwest of GZ the narrow valley widens onto a gently sloping bench, Morrisania Mesa, that extends almost to the Colorado River. Battlement Creek crosses this bench and enters the Colorado about 5-1/2 miles northwest of GZ.

Figure B-1 shows the location of RULISON GZ in relation to Battlement Creek and the Colorado River. The approximate elevations of several points of interest in the area are as follows:

Location	Approximate Elevation Above Mean Sea Level
Colorado River at mouth of Battlement Creek	5,140 feet
Lower end, Morrisania Mesa	5,700 feet
Upper end, Morrisania Mesa	6,400 feet
RULISON GZ	8,150 feet
Battlement Mesa rim	9,000-10,200 feet

*For additional information on the ecological setting of Project RULISON see "Pre-event Bioenvironmental Safety Survey and Evaluation, Project RULISON." PNE-R-3, July 28, 1969. (Available from: Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U.S. Dept. of Commerce, Springfield, VA. 22151.)

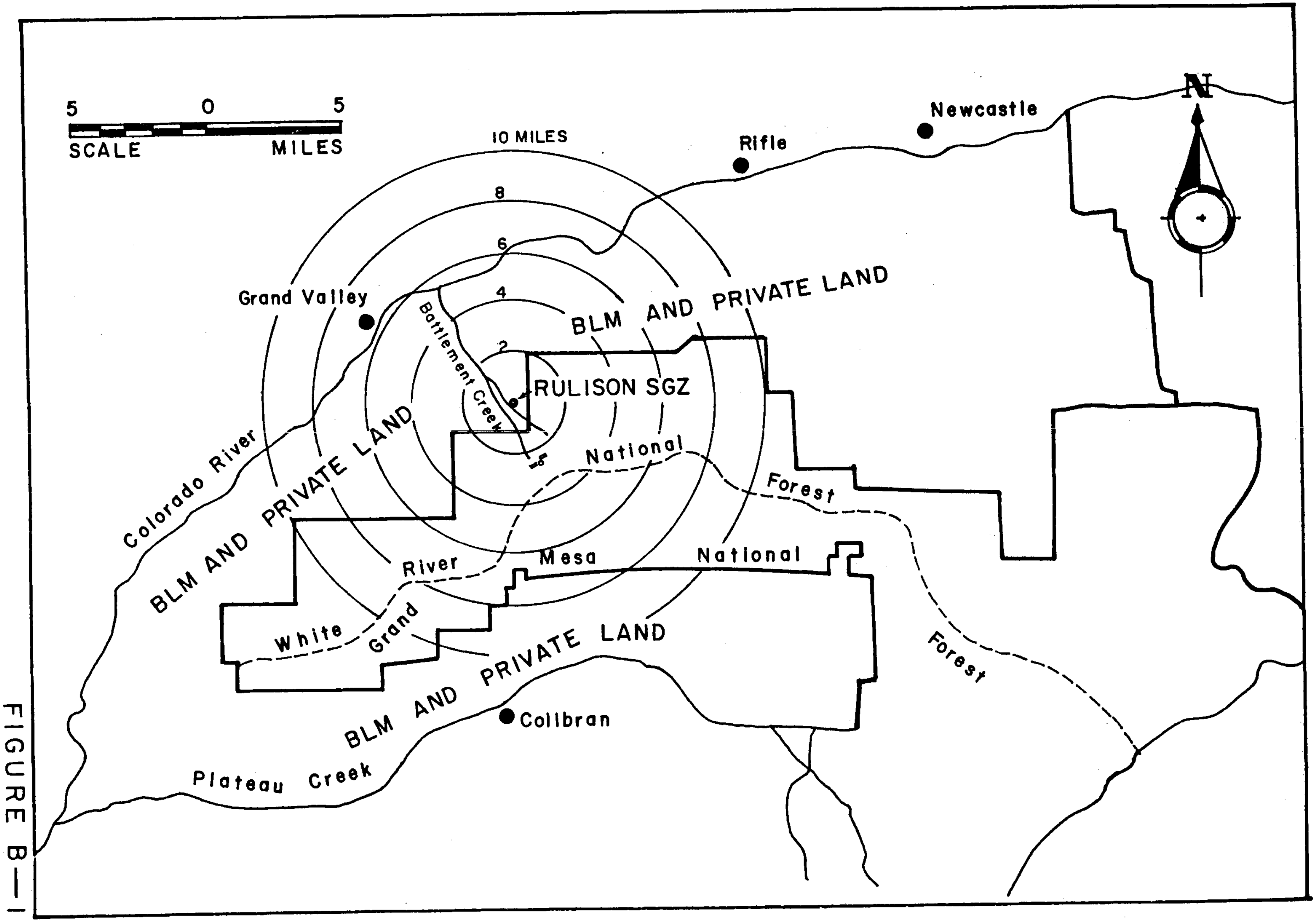


FIGURE B—1

PROJECT RULISON SITE AREA

BLM = BUREAU OF LAND MANAGEMENT

2. Vegetational Cover

Morrisania Mesa (cultivated area)
Alfalfa, small grains, fruit orchard (apples, apricots, cherries, peaches, plums), kitchen gardens, irrigated pasture.

Morrisania Mesa (non-cultivated area)
Big sagebrush, grass, forbs, Pinyon/Juniper (with Juniper predominating).

Battlement Creek valley, lower end
Pinyon/Juniper, mainly on southwest - facing slopes to about 7500'; Oak (Gambel's)/Mountain Mahogany from 6500' to 8500' (service berry and snow berry are included at higher elevations); Cottonwood/Willow/Alder along stream bed up to about 8000'.

Battlement Creek valley, upper end.
Quaking Aspen (starting at about 8000' in valley floor and extending, in extensive groups, to top of mesa), Douglas Fir (starting at about 8000' and extending to top of mesa) Engelmann Spruce (at upper reaches of the valley and extending onto the mesa).

Battlement Mesa
Grassland (fescue, poa, brome and various forbs; sedges in wet areas); Browse (oak brush, service berry); Quaking Aspen (in groves, with grass and forbs on forest floor); Engelmann Spruce, in pure stands or in association with Alpine Fir.

3. Land Use

Cropland - Morrisania Mesa, below RULISON GZ, reportedly has about 1900 acres of cropland, irrigated from Battlement Creek. Crops include alfalfa and grass hay, fruit orchards and irrigated pasture. Most of the 30 households on the Battlement Creek ditch system have irrigated kitchen gardens.

Range Livestock - Beef cattle comprise the main livestock production in the vicinity of RULISON GZ. Cattle are wintered (from December to mid-April) on the benchland along the

Colorado River. Principal winter feed is hay, most of which is produced locally. Starting about the middle of April, cattle go onto native forage on private lands and move onto Bureau of Land Management (BLM) allotments about May 1. The BLM Battlement Creek Common Use Allotment, immediately down the valley from RULISON GZ, provides grazing for about 200 cattle units (cow and calf) from May 1 through June 15. From June 15 through October 15, the cattle are on National Forest land on the upper slopes and top of Battlement Mesa, after which they are moved down to pasturage at lower levels on BLM or private land. The carrying capacity of the National Forest range on the Battlement Creek Cattle and Horse Allotment (ca 11,000 acres south, southeast and east of RULISON GZ) averages about one cow unit (cow and calf or 1.5 yearlings) per 29 acres. However, about half of the total acreage is rated as unuseable (bare rock or dense timber without forage value), so the actual pasturage supports about one cow unit per 15 acres. This suggests a fairly dense vegetation and good productivity on the useable part of the range.

4. Wild Game and Fish Resources

The most important big-game species found in the vicinity of RULISON GZ is the western mule deer. The deer winter (from December through April) on the benchlands along the Colorado River, including Morrisania Mesa. From as early as mid-April to as late as mid-May, depending on weather conditions, the deer start moving up the slopes toward summer range on top of Battlement Mesa. The migration from summer to winter range occurs from late October through November. Deer migrating between summer range on Battlement Mesa and winter grounds on Morrisania Mesa and adjoinging Holmes Mesa move through Battlement Creek valley, passing close to RULISON GZ.

During winter and during migrations the principal deer browse plants are big sagebrush, service berry, mountain mahogany and Gambel's oak. Forage during the summer is reported to be mostly forbs.

In 1969, the deer hunting seasons in Management Area 42, where RULISON GZ is located, were as follows: archery season - August 16 through September 14; regular season - October 18 through November 6.

Small populations of elk and bighorn sheep are found in the vicinity of RULISON GZ. The total summer elk population on Battlement Mesa is estimated to be about 250 animals. During the summer the elk range widely over the Mesa. By the end of December, they are off the Mesa top and on their winter grounds in the upper valleys of streams originating on Battlement Mesa. Some 15-20 elk winter at the head of Wallace Creek, southwest of RULISON GZ. Another 60-75 animals winter on the upper Mamm and Divide Creeks, 15-20 miles east of GZ. The balance of the Battlement Mesa elk herd spends the winter in the Plateau Creek drainage, south of the Mesa.

The regular hunting season for elk in 1969 was October 18 through November 6. The archery season was August 16 through September 14. No statistics are available on the number harvested. Based on previous seasons, it is estimated that the number taken in the entire Battlement Mesa area will not exceed 50 animals.

An estimated 75 head of bighorn sheep range on the rocky western tip of Battlement Mesa, 8-10 miles southwest of RULISON GZ. About 6 sheep permits are issued each season but usually only 1-2 animals are taken.

Blue grouse, sage grouse and wild turkey are hunted to some extent in the RULISON site area, mostly by local residents. No statistics are available on the number harvested.

Battlement Creek and the Battlement Reservoirs in which the creek originates are both fished to some extent, mainly by local residents. The reservoirs have been stocked with cutthroat trout and fishing is considered good in them; however, they do not attract large numbers of fishermen because of difficulty of access. Battlement Creek is stocked with rainbow trout and has a native population of cutthroats. No statistics are available on fishing pressure or catches.

B. PREDICTED EFFECTS OF POST-SHOT ACTIVITY ON THE LOCAL ENVIRONMENT

Over the years a wide variety of plant and animal assemblages, representative of major ecosystems throughout the United States, have been experimently exposed to various kinds and amounts of ionizing radiation. Ecological effects attributable to radiation have not been detected at radiation levels to which the RULISON area may be exposed, even when a maximum hypothetical accident case is considered.

In addition, a special Ad Hoc Panel of Reviewers, whose members included biomedical and ecological experts not associated with RULISON, has evaluated the proposed Post-Shot activities. The panel concluded that:

> "Ecological effects in the natural environment, distinguished from that of man and his domestic species, are not anticipated, e.g., on the deer populations and their winter ranges."

Nevertheless, some of the environmental samples collected during flaring operations will be analyzed and compared with information presently predicted from the modeling program. In this manner the "state of the art" to predict ecological consequences from this type of activity can be refined.

December 22, 1969

Mr. Robert E. Miller, Manager
Nevada Operations Office
U. S. Atomic Energy Commission
Post Office Box 14100
Las Vegas, Nevada 89114

Dear Mr. Miller:

Members of the Ad Hoc Rulison Review Panel reconvened on December 22, 1969, to hear and discuss comments resulting from our report of November 21, 1969.

Comments of the Panel are herein again presented in two parts: (1) engineering and (2) bio-environmental aspects of the re-entry and testing operation. Modifications of our previous recommendations are the result of clarification of our comments as well as that of AEC and others associated with Rulison.

ENGINEERING

After a review of the limits imposed by AEC on the quantities of gas or other well fluids which can be allowed to escape, the Panel alters its opinion on BOP testing. Industry practice is not concerned with the loss of minute quantities of fluids from the well and some seepage is allowed to occur at test pressures. This loss is on the order of less than 10 cf/hr but we are informed that for the purposes of this operation AEC desires no measurable loss.

In view of the difference in test criteria, we would agree that the more frequent testing (once per day) and the testing of the Hydril to its working pressure is satisfactory. Implicit in this concurrence, is our understanding that replacement of rubber parts is anticipated upon the discovery of even the most minor leak.

The only operations which are to be restricted to daylight hours are the removal from or insertion of the drill string into the well bore under pressure. This also applies to producing strings of tubing and other downhole producing equipment.

BIO-ENVIRONMENTAL

In addition to the environmental monitoring program as described, the Panel would also urge that an effort be mounted to sample urinary tritium levels on some small number of local inhabitants, including children. Such measurements would be invaluable in validating dose estimates to the local population based on measurement of dietary and water levels. Such a sampling program should begin sufficiently in advance of reentry to provide adequate baseline data. This recommendation is made not from any concern that dose estimates as presented represent a hazard, but rather to provide confirmatory information which will be useful in subsequent Plowshare programs.

SUMMARY

In summary we can only reiterate what we stated in our previous report, namely, "Based on implementation of the above recommendations and the material presented to us during this review, we believe that completion of Rulison can be accomplished within acceptable safety standards."

Respectfully submitted,

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November 21, 1969

Mr. Robert E. Miller, Manager
Nevada Operations Office
U. S. Atomic Energy Commission
Post Office Box 14100
Las Vegas, Nevada 89114

Dear Mr. Miller:

Members of the Ad Hoc Rulison Review Panel met on 20 and 21 November, 1969, at the AEC's San Francisco Operations Office to review data concerning predictions and evaluations of bio-environmental as well as engineering aspects associated with re-entry, gas reservoir testing and flaring. Considerable discussion was stimulated during the review period and the Panel appreciates the opportunity to participate in this Plowshare activity. In general the Panel feels complete confidence in the adequacy of safety preparations and that the extremely small potential risks are well within acceptable limits.

The comments of the Panel are presented herein in two parts: (1) engineering and (2) bio-environmental aspects of the re-entry and testing operation. In addition a rather precise statement of our conclusions concerning the safety aspects of the operation is appended.

ENGINEERING

Comments on Appendix "A"

The plans and equipment described in Appendix "A" provide a near minimum risk operation. Several points, however, are worth consideration.

1. In view of the previous problems with mud contamination of stream water, a dike or holding pit arrangement should be provided to catch any drilling or washdown fluids which might escape the circulating or storage pits.

2. The testing procedure outlined for the BOP system is excessive to the point that it will be detrimental to safety. The daily

operation of RAM-type BOP's is desirable, but pressure testing weekly is preferable since pressure applications eventually degrade the integrity of the various seals included in BOP's. More important is a restriction on testing of the Hydril. It should be tested to its working pressure once when installed. Thereafter, testing should be restricted to weekly operation and pressure application restricted to 1,000 psi. At these tests the Hydril should be closed only on the largest diameter pipe normally run through it.

3. Every effort should be made as soon as possible and periodically to sample the gas from the R-E well. Several purposes will be served. Analyses will be invaluable when re-entering the chimney. Withdrawal of a small amount of gas may aid in determining the condition of the stemming material in the well bore.

4. For practical purposes, no hazard is existent in this procedure except for a few relatively short periods. Although these periods are critical, they are conditions which are encountered in normal oil and gas drilling operations (often unexpectedly) and techniques are readily available for their control.

   Fractures may radiate outward from the chimney to some distance. Should such fractures be encountered, a partial loss of drilling fluid may occur. It is also possible that some gas may be circulated to the surface with the returning drilling fluid. This gas and the drill cuttings returning with it would be radioactive and it would be necessary to adequately control and dispose of these materials. The pressure in the chimney is insufficient to blow 9.0 ppg fluid from the hole should the pressure be encountered below 6,500 feet.

   Should the bit encounter the chimney void space without warning the drilling fluid will drop rapidly and the well pressure will be applied at the surface.

   The most critical operation to be performed is the removal of the drill pipe and insertion of the downhole production equipment. These operations should take place only in daylight hours. Testing, flaring and effluent handling procedures and equipment are adequate and pose no problems. Possible leakage from all tanks, vessels, and receptacles should be protected by adequate dikes. A 24-hour guard patrol should be provided on site after testing commences.

   In summary all of the plans and procedures for re-entering and testing represent standard operating procedures for oil and gas drilling and production operations. These procedures are dependable to the degree that the probability of an occurrence of the AEC's maximum credible accident is in the order of less than one in one million.

BIO-ENVIRONMENTAL

The Panel is pleased to note that the safety aspects of Rulison involve the standard operation procedures followed by the Nevada Operations Office as well as additional activities specifically designed for Rulison. We realize that some of these additional activities are not warranted from an implied risk, but are highly desirable as a result of unique problems arising from public concern.

Essentially our comments can be summarized as follows:

1. It is vital that reliable radionuclide background values for selected foods and water of wildlife, domestic livestock and humans be obtained prior to re-entry. Emphasis should be on tritium levels.

2. Engineering operations during and following re-entry (2 or 3 days) should not be conducted under periods of unusually heavy rainfall.

3. Available data on fetal mortality, cancer incidence, current cancer cases, medical resources, and characteristics of the medical data available should be obtained prior to re-entry for the surrounding communities, even though we firmly believe that there will not be an increase in cancer or fetal mortality resulting from Rulison.

4. Predictions of radionuclide contamination in the environs should not only include the worst possible case but, more appropriately, the most probable case. That is, we encourage consideration of the worst case provided that it is accompanied by a statement of the probability of such an event as well as an evaluation of the most probable event.

5. In all future sitings of detonations for oil and gas fields, consideration should be given to biomedical and ecological factors as assessed by professionals in these fields.

6. Ecological effects in the natural environment, distinguished from that of man and his domestic species, are not anticipated, e.g., on the deer populations and their winter ranges.

7. Although not specifically applicable to Rulison, we feel that consideration should be given to monitoring select personnel in future operations of this type, as research opportunities exist and not because of our concern for undetected injuries in the past. For example, this might be done by monitoring urine samples of the rad-safe monitors.

SUMMARY

Based on implementation of the above recommendations and the material presented to us during this review, we believe that completion of Rulison can be accomplished within accepted safety standards.

Respectfully submitted,

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